Compromising the Environment?
The Spruce Budworm, Aerial Insecticide Spraying, and the Pulp and Paper Industry in New Brunswick

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Abstract

Continual growth of the New Brunswick's pulp and paper industry since the late 1920s eventually brought the industry into conflict with the eastern spruce budworm (*Choristineura fumiferana*). This paper explores the evolution of budworm management since the 1950s, through an examination of the justifications behind the chosen control strategy of aerial insecticide spraying and the development of these justifications over time; through an examination of the criticisms of the spray program and the forest management practices that were linked to it; and, through an analysis of the design of the proposed control program for assessing responses to past criticisms.

Contents

Foreword

The relationship between this Major Paper and my Plan of Study, the area of concentration titled “Science Perspectives in Forest Management”, is as follows. The Major Paper’s analysis corresponds to all the objectives and strategies presented in the Plan. Two of the “components” of the Plan, “the political economy of forestry” and “the role of science in forest management” were both very important themes in the Major Paper analysis. The third component, Canadian forest ecology, is broader in scope than the analysis presented in the Major Paper. The “spruce budworm-forest relationship in New Brunswick” more accurately categorizes the scope of the Major Paper in relation to this component. “Canadian forest ecology” is a more fair term for the purposes of encapsulating the general scope of study (of forest ecology) through the MES I and II phases of the program, when I was still considering a few different subjects for research. Considering this relationship between the components and the Major Paper, the objectives and strategies of the Canadian forest ecology component are not as closely related to the goals of the Major Paper as the other two.

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Amongst the Faculty members, I must offer a great thanks to Anders Sandberg, who supervised my Major Paper as well as independent studies. His many criticisms of my work—many red pens must have lost their lives—helped to make me think very carefully about my use of language and about clarity of content and structure in my writing. I feel that my research and writing skills have improved greatly as a result. I also would like to thank Bryn Greer-Wootten, who was very patient and helpful during the long time period I took for writing my proposal. Additionally I add thanks to Bev Altberg for making the Student Programs Office a more interesting place, and for keeping me running.

I also must acknowledge the many students I met through York’s Faculty of Environmental studies and the many thought provoking conversations we had. These were, no doubt, very strong influences in shaping my ideas during the last three years. Many of these conversations took place in “Counter Culture”, and the fine vegetarian and vegan food there as well as the staff were great, especially considering they did not have me removed for loitering. Before even arriving at the Faculty though, there was another influence who was probably the most significant from an environmental standpoint. The many conversations I had with her truly led me to challenge many of my beliefs about society and the relationship between humans and nature. This was where my learning process in environmental studies actually started. I consider this to have been a very positive turning point for me. Thanks Amy.

Introduction

> I shall never cease to wonder at the collective power of billions upon billions of budworm larvae and how in the space of a few years, working about one month a year, this power can change the forest over thousands of square miles—something man could not do in ten times the time working year round (Flieger 1953, p.10).

For over 50 years, the eastern spruce budworm (*Choristoneura fumiferana* (Clem.)) has been seen to stand in the way of increasing development of the pulp and paper industry in New Brunswick. The battle that has ensued—spray planes versus worms—has involved much controversy. The pulp and paper industry has been perhaps the most dominant force in the economy of the province over the past 70 years (Parenteau 1992). The budworm has caused the industry such worry because the tree species whose foliage it feeds on are the balsam fir and the spruce species that represent the vast majority of the area's valuable pulpwood trees. The eastern spruce budworm is relatively tiny, about 2 cm long and less than 2 mm wide during its hungriest phase (Morris 1963, p.15), but due to the massive population levels it reaches in outbreak conditions, the effect on the forest is enormous. Pure stands of mature and older balsam fir are so defoliated that they are nearly all killed during outbreak peaks, and high mortality of mature and older white spruce occurs as well (MacLean and Ostaff 1989, MacLean 1990). Other species affected are red spruce and black spruce, in decreasing order. Although it is quite clear that such a situation presents great difficulty for the pulp and paper industry, the questions on why this is the case, why the industry chose the management strategy it did, and how it was justified, are more difficult to interpret.

The ensuing discussion examines the present budworm management strategy in New Brunswick and how it has evolved in response to environmental criticisms (listed further below) of the spray program since it began in 1952. The analysis will proceed through three stages. In Chapter One, the rapid and extensive development of the pulp and paper industry during the first half of the 20th century will be described. This will bring light to how the goals of industry for management led to the insect becoming so important—and management of it so desperate. During the spray program, the budworm arguably became more of an enemy in New Brunswick than anywhere else in its eastern North American range. Chapter one also contains an extensive analysis of the spray program and some of its justifications.

In Chapter Two, criticisms of both the forest management practices of the pulp and paper industry and the spray program (inextricably linked) will be analyzed in detail. Early criticisms of forest management were given in the 1920s (Tothill 1922, Craighead 1924), when the pulp and paper industry was starting to fill its presently dominant role in the province's economy. Criticisms of the way forests were managed leading up to this time, and how these criticisms were the basis of early silvicultural budworm management strategies, will be described. This will be followed by an analysis of further criticisms that arose during the spray program, which included an extremely heated debate over human health problems and their link to forest spraying (Miller 1993).

In Chapter Three, ways in which the presently proposed budworm management strategy *may* reconcile or fail to reconcile the themes identified in Chapter Two will be discussed. Throughout the 1990s, while the budworm was scarce, Canadian Forest Service scientists developed the Spruce Budworm Decision Support System (Sanders 1995, MacLean 1996, MacLean et al. 2001), championed as a technological innovation in forest protection. With it, the expectation is that past outbreak conditions can inform future management decisions. A computer program allows users to make hypothetical management decisions, and the expected outcomes to the forest (and timber volumes) will be displayed, including the effect of different harvesting levels and of various spray applications or the lack thereof. Also important in the new approach is the proposed use of the biological insecticide commonly known as Bt. It has been hailed as the environmentally safe heir to the synthetic chemical insecticides used in the past (Smith 1998, Restino 1993, Canadian Forest Service 2000). In order to clarify to what extent past criticisms have been reconciled with environmental concerns, the new and modified control measures will be analyzed through criticisms of past management. In order to accomplish this, the themes that are used to characterize criticisms of the past control program will be used as a basis to assess how the new strategy has evolved in response to them. Concluding statements will follow.

Some elements of this paper have already been explored in other literature. Sandberg and Clancy (2002, in press) have examined the intersection between science, politics and public policy in assessing how different approaches to managing the spruce budworm were taken in New Brunswick and Nova Scotia. This paper overlaps to some extent in the analysis of the scientific framing of the budworm problem and scientific justification of the control approach in New Brunswick. Gordon Baskerville has been heavily involved in contributing to the budworm control debate from the 1970s to the 1990s. In 1995 (Baskerville 1995) he produced an extensive overview of the budworm "problem" from the point of view of industry and forest scientists focused on advancing industrial productivity. Baskerville's work has been heavily referenced in the present analysis, and his 1995 contribution was very important for framing the industrial point of view that was one of the main themes of the first chapter in this paper. Miller and Rusnock's 1993 paper, "The rise and fall of the silvicultural hypothesis in spruce budworm management in eastern Canada", covered in detail the controversy over the scientific integrity of silvicultural control in New Brunswick. This same debate is a very important theme in this paper and there is certainly a lot of overlap in this case.

Where this paper may extend into different territory from these other contributions is that it is a comprehensive exploration of how the justification of aerial insecticide spraying developed over time, how the argument for alternative approaches developed over time, and how the arguments against the aerial spray approach developed. It then goes further by exploring how the past debates and discourses relate to the proposed approach. The best way to describe it is as an evolutionary analysis.

This is an interesting time to review past budworm management in New Brunswick because at present, the spray program has been halted due to very low budworm populations (Smith 1998, Kettela 1997). Outbreak conditions have not existed in the province since around the mid-1980s, so there has been plenty of time and resources to devote to preparing alternatives to chemical insecticides. The time to prepare for another outbreak is growing short though. Another outbreak is expected to arise essentially any year now (Smith 1998, MacLean 2001).

Chapter One:

The Emergence of the Pulp and Paper Industry and the Spruce Budworm Spray Regime in New Brunswick

The discussion in this chapter will focus on identifying ideas that built up the case for justifying the insecticide spray program, and on how these ideas have evolved up to the present. Extensive and intensive spraying of spruce budworm began suddenly in the 1950s as an outbreak was underway, but it was in the first 30 years of the 20th century that an industrial transition changed the shape of forest harvesting—an important precursor. The pulp and paper industry was growing, gradually replacing the lumber industry, and the change had the effect of creating a more desperate wood supply situation by the 1950s. Conditions were created where the spruce budworm was continually perceived as a greater and greater danger. As is explained further in the discussion below, such conditions would prevail so as to make an acute and risky control measure—aerial insecticide spraying—almost a forgone conclusion. As the budworm became more and more of an enemy, with the spray program well underway, justifications for the chosen protection strategy continued to build.

The Rise of the Pulp and Paper Industry

From the early 20th century to the late 1920s, the province of New Brunswick underwent a transition from an economy dependent on lumber to one based on pulpwood (Parenteau 1992). Economic opportunity pushed this transition forward. In the early 1920s, the lumber industry collapsed with timber revenues falling to half of previous values. This coincided with a short depression in 1921. The province was desperate from this loss of economic revenue, so it acted by filling the void with heavy investment in the pulp and paper industry, which included facilitating the access of companies to Crown land and giving them water power concessions (Parenteau 1992).

The resource development opportunity for pulp and paper companies had been building up for some time before this government assistance. The forests of New Brunswick had already been depleted of quality timber. Large trees that were accessible were lacking, which put the lumber industry in the province at a natural disadvantage. The pulp and paper industry offered a perfect opportunity to profit from the so-called *leftover*, smaller trees (Cote 1979); productivity of this industry depended not so much on the size of individual trees, but on wholesale volume. Another factor that aided in the development of the industry was outside competition. Previous to the 1921 depression, the Panama Canal had been constructed (1914), and through this route, cheap Western lumber was transported that outsold products of the Eastern forest (Cote 1979). This made reinvestment into lumber production unwise. Altogether, these factors encouraged increasing investment into the pulp and paper industry throughout the 1920s, and a consequent loss of interest in restoring the population of large spruce and pine. Thus, the harvesting and management demands on the forest were changing, and the shift necessitated a change in what trees would be regarded as valuable.

In the beginning of the 20th century, the fledgling pulp and paper industry was entirely dependent on spruce species. This had repercussions. One forester, Ellwood Wilson, explained in 1909, "As spruce has been a favourite wood for pulp, its removal has favoured the balsam, which is coming in rapidly everywhere and crowding out the spruce" (Swift 1983, p.175). By the beginning of the 1920s, after a major spruce budworm outbreak had just passed, balsam fir was just starting to become an economic species (Tothill 1922), but its value was increasing quickly. By the 1930s, the pulp and paper industry had begun to exhaust its supply of good black spruce, and the importance of balsam fir grew prominent (Swift 1983). This was reflected upon a few decades later: "At one time disdained as a weed tree, balsam fir became New Brunswick's Cinderella species three or four decades ago when industry in New Brunswick obtained the technology to permit its wholesale use in the manufacture of newsprint"(Marshall 1975, p. 143).

The increasing amount of balsam fir made the potential of another budworm outbreak greater and the increasing dependence of the pulp and paper industry on the species heightened the concern (Maritimes Forest Research Centre 1972). The transition to a heavy dependence on balsam fir was almost by necessity, since other immediate options had practically been exhausted. Limits to production were not foreseen, or at least not regarded as legitimate. A 1922 forecast for a budworm outbreak to appear in the early 1950s (Tothill 1922), even though it included forest management recommendations, did not result in action.

The "Need" for Spraying

Tension over possible pulpwood supply shortages arose in the 1940s when the supply of mature black spruce started to dwindle. As described by Kettela (1975, p.141), "Earlier outbreaks were tolerated by established sawlog companies and fledgling pulp producers relying on untapped reserves. But since the 1940s, the finite nature of the forest inventory has become very evident, and industry, particularly in New Brunswick and Quebec, has needed to protect its resource base." What is particularly noteworthy about this statement is that the presence of "untapped reserves" allowed past outbreaks to be ignored, while this luxury was not present by the 1940s. Flieger (1953, p. 11) also indicated that there was “more forest than the industry was able to exploit”, at least through the 1920s. It is apparent that little concern was present even in the 1930s, since there is some evidence of epidemic populations of budworm during this time (Flieger 1953, Swift 1983), but no subsequent action. However, these were likely localized surges in the budworm populations, not forest-wide outbreaks. A full outbreak would not become apparent until the late 1940s (Baskerville 1975a, MacDonald 1968).

The pressure on the pulpwood supply that arose in the 1940s was exacerbated when the provincial government made a move for economic development of the softwood-based economy. Encouragement for this came from a federal/provincial agency called the Atlantic Development Board (Baskerville 1995). The goals were to increase economic activity by expansion of existing companies and enticement of new ones. Bolstered by the increased demands on the forest, pulp and paper companies were encouraged to harvest greater quantities. This pressure, as indicated in Kettela’s statement above (“lack of untapped reserves”), made the budworm more troublesome, and was likely the justification for industry to pursue an acute control measure, which was aerial insecticide spraying.

This aerial management *solution* became an attractive option in the years preceding the outbreak that began in the late 1940s. The success of DDT in controlling insect populations in World War II prompted the tests for its use in forest management. The experiments were conducted in Ontario in 1944-46 with the objective of determining the "effectiveness and economy" of aerial insecticide spraying to combat budworm (Ontario Department of Lands and Forests 1949). At this time, DDT was made available to the Canadian government for experimental purposes, to see if it could be used successfully against budworm without drastically damaging the forest ecosystem (Miller and Rusnock 1993b).

The effects, very briefly, were as follows. Almost complete destruction of aquatic vertebrates was discovered in sprayed and downstream areas; heavy death tolls were found in amphibians and reptiles, and in stream fish in slower moving water; small mammals were killed when contacted by a heavy dose; and, the overall, encompassing effect on all forest fauna was unknown, needing future study. One of the greatest concerns was over stream fish. The aquatic insects the fish depended on for nourishment were almost totally wiped out, but the study did not conclude that starvation of stream fish, a potential economic blow, was inevitable. It was instead thought that retarded growth would be the main effect because food would be available for at least part of each season, and sprayers could also avoid direct application on fish habitat.

Overall, the study found that the high toxicity of DDT on budworm and apparent lack of *disastrous* effects to other wildlife gave validity to aerial DDT spraying as an effective management technique. The conclusion, that a lack of disastrous effects made DDT relatively safe, was based on tests conducted over only three seasons, from 1944-1946. It seems, from this assessment, that a relatively high degree of short-term non-target damage *had to* be justified for economic production of the desired softwoods. What is meant by "lack of disastrous effects" was that no evidence of *absolute* destruction of non-target species was apparent. The almost complete destruction of aquatic invertebrates (aquatic insects inclusive) was only mentioned as important due to the effect on economically important fish. Again, some degree of non-target damage was accepted, and this point will be returned to further on. The fact that DDT was pronounced relatively safe after only three seasons of testing seems to indicate that it was only intended as a short-term measure, possibly with the capacity to eliminate an outbreak in a few years.

These tests were important for opening the door on DDT use in forest management. With field trials being declared successful, and commercial spraying operations in Oregon between 1949 and 1951 suggesting success, the attention of the pulp and paper industry in New Brunswick was caught (Balch 1952). At the beginning of the 1950s, the industry began to lay the groundwork for an aerial DDT spray program. What followed was an extremely large investment and extremely rapid development of infrastructure. The New Brunswick International Paper Company (NBIP) put forth the initiative. Two foresters with the company, L.S. Webb and B.W. Flieger were very familiar with effects of the previous outbreak of 1912-1919, and realized that there was potential for destruction of the company's timber supply. It was decided that the only hope for protecting the company's present and future timber supply lay in aerial insecticide spraying (Balch 1952). The province collaborated to share its costs, and incidentally, the aircraft were already available—World War II bomber planes. Another important piece of the operation was Budworm City, construction completed by 1951 (FPL website). It contained a laboratory where much of the early work on spray efficacy and biological tests was done, a dirt airstrip for the spray planes, and living quarters for 200 men. The first spray operation was conducted in 1952 as a joint venture between NBIP and the province, using a 200,000-acre area that was part of the company's lease. This initial cooperation between industry and government led to the formation of a company, Forest Protection Limited (FPL), which was incorporated in August of 1952, very soon after the first spray operation (FPL website). Its initial sponsors were Bathurst Power and Paper Company, Fraser Co.'s Ltd., J.D. Irving Ltd., and NBIP (Balch 1952). This represented most of the pulp and paper interests in the province at the time.

The rapid development of the spray program took just over two years, despite the great degree of work involved. The infrastructure and investment for the spray program was put into place very quickly and without diversion into other operational measures. The heavy dependency the industry had developed for susceptible species, the lack of available timber reserves (relative to the demand), and a high expectation for the spray to have dramatic positive effects on saving valuable timber were all reasons for the rapid development. The program was deemed cost-effective—though, as will be shown in more detail in the following chapter, only conditionally. The impression given by the spray advocates was that enough tree mortality would be prevented to allow sufficient excess harvesting in the future to cover the costs of the program.

The Budworm as Enemy and Competitor for Pulpwood

Along with the industry's high dependency on susceptible species, further justification for the intense management of budworm populations came with the portrayal of the spruce budworm as a competitor with or an enemy of the industry. Even before the spray program began, the budworm had reached *enemy status*. A forest engineer in the 1930s, for example, considered its effect on the forest during heavy infestation as quite horrifying:

> Fat, greasy crawling worms everywhere…stinky, messy hairs hanging everywhere…motheaten woods with dead needles and excrement falling like rain…followed in a year or so by such an attack of borers—those ghouls of the dying forest, as has never been witnessed in Canada. To anyone in the budworm-ravaged forest at the time when the beetles were emerging, it was a nightmare experience (quoted in Swift 1983, p. 173).

The depiction is perhaps not surprising considering the extensive mortality and change in the immediate forest environment that a budworm outbreak can cause. Clearly, the picture painted in this description is of a rather horrific enemy.

The depiction of insects in general as horrifying—and as enemies—was deeply rooted. In 1922, for example, the chief of the United States Bureau of Entomology had the following to say:

> The Great War proved what can be accomplished in the field of science when concentrated and concerted energy is applied as a result of a powerful incentive…Henceforth this warfare between man and the insects is to be one of relentlessness and determination. It will be a warfare which knows no armistice. Man's civilization, his future, his very life, are at stake (quoted in Russell 2001, p. 77).

In a publication by New Brunswick International Paper Company (1952), titled *Battle of the Budworm*, the references to the budworm as the enemy were obvious. In this pictorial story, the caption describing the launch of the first spray mission read (p. 16), "They're off! On June

13th, entomologists reported the insects at the proper stage of development. At 3:00 a.m., June 14th, the weatherman answered the sprayers' prayer: 'no wind-no rain'. The big day had arrived! The time was now!" A paraphrasing of this can be that the enemy was in sight and the army was poised for attack. Such adversarial approaches towards insects were common and were a common theme in the aerial insecticide spray "war" on the budworm.

Justification for the portrayal of the budworm as an adversary is perhaps clearer when related to the importance of timber volume to the industry. When commercial spray operations began, the budworm was described as a competitor with humans for harvesting *rights* for pulpwood. Flieger (1953, p.16, my emphasis) stated that "Forest spraying keeps trees alive—of this there is no doubt. The outcome, then, unless some new trend appears, seems to depend mainly upon the relative *persistence of the insect in epidemic form on one hand and the forest sprayers on the other*". In Baskerville's words, "in the last 40 years, industry has decided that balsam fir, red spruce, and white spruce are desirable species and consequently finds itself *competing with the insect for the option to harvest*" (1975a, p.140, my emphasis). The portrayal of the budworm as such an enemy or adversary was perhaps necessary in order to justify such a pronounced infliction of destructive force on the species. It would be hard to imagine the forest products industry becoming too upset if the budworm were to appear on an endangered species list.

Rationalization of Spraying, Justification of Costs

With a competitive stance against the budworm in place and the necessary groundwork finished, the spray program was established. Initially, there was great optimism about the immediate effectiveness of the approach, and it was not expected to be a continuous, long-term measure. The original goal behind the aerial spray program was to reduce budworm density enough to allow a return to pre-outbreak conditions within a few years of initial spraying (Kettela 1975). Complete stoppage of defoliation was not regarded as a possibility, but there was a definite expectation that after preventing tree mortality for a few years, the outbreak would subside naturally. In Balch's words (p. 209), "The objective was not to halt the outbreak, but to prevent the trees from being killed by protecting them from complete defoliation until the outbreak subsides." The opinion of FPL manager Barney Flieger (1953) was that, "…a limited area of valuable forest might be treated over a period of time as long as ten years (not every year). This might mean not more than three or at the outside four applications of insecticide."

Spraying insecticide was costly, so the goal was "to afford just enough protection to keep trees alive at the lowest application rate over the least acreage" (Kettela 1975, p. 140). As many pulpwood trees as possible had to be kept alive in order to satisfy the economic demand. The only limiting factors to pulpwood production were the ability of the forest—with the aid of human technology—to produce fibre and the speed of humans at harvesting. For the spray approach to be cost-effective, the sprayers had to know specifically where to target the insecticide to achieve the most significant reduction in defoliation. Spraying every forested area in the whole province was not economically possible (Baskerville 1995). New Brunswick's spray operations were planned based on hazard maps. The Canadian Forestry Service developed the system of hazard mapping in the early 1950s (Webb 1956, in Kettela 1975). The focus of the mapping effort was to find the areas most likely to suffer tree mortality due to budworm feeding. Aerial surveys were compounded with ground surveys to estimate defoliation amounts, which were considered alongside egg mass counts. Altogether, the result was a hazard index for each location. Hazard indices were plotted on a map and the location of high hazard areas would neatly show the areas where spraying was a priority.

At this early point in the spray program, spraying was described as being the only legitimate option for the pulp and paper industry's purposes. The fear was that the only alternative to spraying was to accept a catastrophic loss of the province's pulpwood supply (Blais 1968, Baskerville 1995). The pronouncement of spraying as the only option was backed up with an early rationale. Balch (1952) explained that the budworm disturb the ordinary balance of nature because it is not controlled "adequately" by natural factors. Although it was believed that management should focus on creating forests more resistant to attack—through means of biological control, parasites, and diseases—the approaches were never tested at a practical level, so they could not have made an immediate impact. Balch's conclusion was that a more direct method (spraying) was needed to manage the current outbreak. This point was echoed over 20 years later as Marshall (1975) explained how, at the outset of the spray program, silvicultural management could have little effect in the short term, while the attractive idea of biological control was not available as a practical option. His conclusion was that given the demands the industry placed on the forest, spraying was the only way to protect the crop.

Since spraying was regarded as the only option, damage to non-target fauna had to be accepted as the program became operational. As described already, the initial tests showed that DDT was destructive to non-target species in the short-term, but it was not anticipated that spraying would have to be conducted for more than a few years consecutively, certainly not for more than a decade (Flieger 1953). More than two decades later however, spraying operations were still in force, and the logic—that some sacrifices to other forest life had to be accepted—remained consistent. "It's a problem of objectively looking at the total resource balance sheet, and of weighing immediate and future consequences to environmental integrity from spray regimes, against the evident, immediate economic benefits…Insecticide formulations are only weakly selective, and their wide-spectrum toxicity dooms many non-target organisms, including beneficial insects" (Varty 1975, p.146). As explained by Baskerville (1995), "Protecting hundreds of thousands of hectares of infested stands annually by using insecticides damaged non-target populations…Studies found varying degrees of local impact, sometimes severe, but little evidence of impact at the population level" (Baskerville 1995, p. 55). Obviously, whatever the non-target effects were, they were considered unavoidable, and not significant enough to warrant arresting the program.

Prohibitions, Changing Sprays, Unchanging Method

Such scientific and economic justification of DDT spraying continued for more than 15 years, but criticism began to arise against the chemical in the early 1960s. It was largely galvanized by the publication of *Silent Spring* by Rachel Carson in 1962, which generated worldwide attention towards the spraying of DDT in New Brunswick. Particular attention was drawn towards the death of salmon in the Mirimachi River over the first few years of spraying. As described in the book, severe damage to salmon populations in the area was linked conclusively to DDT spraying by the Fisheries Research Board of Canada (Carson 1962, p.132).

Even before DDT was banned however, restrictions had been made on its use. In the mid-1960s, stream banks had already been protected from direct DDT spraying. In reaction to this regulation, FPL began using the organophosphate insecticide phosphamidon—deemed less harmful to fish—over a half-mile buffer strip along stream banks and using DDT over the rest of the area (Kettela 1995). After 1968, the use of DDT was prohibited totally because the effects on non-target fauna were considered too great (Baskerville 1995). Meanwhile, phosphamidon was not viewed to be as effective as DDT from the standpoint of the industry, and its use also had to be restrained (lower doses) because it was considered extremely toxic to birds (Varty 1975, Kettela 1995).

The replacement for DDT was the organophosphate fenitrothion. Its use began in 1969, the year following DDT's prohibition. Controversy over this chemical arose quickly. It was found that an indirect effect of spraying fenitrothion was the damage to blueberry crops resulting from the death of pollinating bees (Varty 1975, Kettela 1995). Spraying of fenitrothion was thence banned within 3.2 km of blueberry fields (Kettela 1995). As well, a restriction was put in place, whereby spray operations were effectively limited to before pollinator emergence, which was earlier in the season than desirable from the sprayers' standpoint. In response to the restrictions, an alternative insecticide, trichlorfon (relatively non-toxic to pollinating bees), was used near blueberry fields starting in 1974. It did not last long; it was considered inferior to fenitrothion in effectiveness and it was last used in 1977 (Kettela 1995).

Another miniature crisis in the spray program occurred in 1974 and 1975, when there was a world shortage of fenitrothion. For these two years, a combination of three insecticides were used: Matacil, Zectran, and Phosphamidon (Blais 1976). Matacil continued to be used in varying quantities—as a secondary insecticide to fenitrothion. The last use of phosphamidon was in 1976 as it got the bad reputation as "the bird killer" (Kettela 1995). In the late 1970s, another hurdle arose due to a worldwide increase in oil prices, which forced spraying operations to focus on greater efficiency. The problems with raised oil prices were both in the fueling of the planes as well as in the formulation of the sprays (oil-based). Greater efficiency was achieved mainly through adjustments in spray machinery, but operations did not necessarily become more targeted to avoid high fuel consumption. The need for protection was considered too great.

Although there had been nearly continuous criticism of the insecticide spray approach since its inception, the most severe challenge to the approach arose through the latter half of the 1970s. This controversy was over fenitrothion's effect on human health and extended into the early 1980s. It involved an apparent correlation between fenitrothion and a deadly childhood disease called Reye's Syndrome (Miller 1993). In 1977, amidst the controversy, a mile no-spray area from habitations was decreed to take care of many complaints of residents living near or in high hazard areas. It was evident that despite the many negative effects on non-target fauna, as well as a possible human effect, the spray approach could not be disposed of. During the time of debate over this illness, many criticisms of the spray approach were brought up. These will be discussed in detail in the next chapter. Despite the concerns however, fenitrothion was not prohibited.

Further controversy over fenitrothion arose later, over its effect on the mortality of forest songbirds. The population of warblers in sprayed areas was reduced significantly in number. At one point, the Canadian Wildlife Service reported that close to one million warblers were killed by fenitrothion spraying in New Brunswick (Lansky quoted in Restino 1993). Use of the chemical continued though, since no feasible alternatives were ready.

Despite the fact that fenitrothion was the main insecticide used throughout the 1970s, around the late 1970s the microbial insecticide known as *Bt* was under serious consideration. This insecticide was unique from others because it was a biological compound from a bacterium native to the area (*Bacillus thuringiensis*), and therefore a natural part of ecosystem processes. At the time, it was described as damaging to the target insect alone, but in actual fact, it is simply more specific to a more exclusive group of insects: lepidoptera (Scriber 2001). Laboratory and field trials were conducted in the early 1970s, and early signs were that Bt could be as effective as fenitrothion; however this was only if it was used at much higher quantities, almost seven times as much (Blais 1976). It was estimated that at least 13 times more aircraft-time would be required, which made Bt prohibitively expensive. Fenitrothion was still considered the primary tool.

Over time, Bt became a more feasible tool. It was tried in a pilot project in New Brunswick in 1979, which was designed to protect woodlots from budworm, but the results were mediocre. When it was tried again in the following year, the results were deemed even poorer (Kettela 1995); however, the opinion was that great strides had been made in Bt research to make it at least an operational alternative (Carrow 1983). Over time, attempts have been made to try and improve the efficacy of Bt through genetic or other manipulation. Significant technological improvements in the efficacy of Bt were made in the 1980s, amidst demands from forest managers and through increased research interests in the area. Through this time period, other eastern spruce budworm-affected provinces decreed Bt-only policies, but New Brunswick did not take this measure. In New Brunswick, fenitrothion was still relied upon by forest managers, making it the only province at the time still using chemical insecticides as a part of its forest management program (Kettela 1995). The chemical was finally prohibited in 1998 due to excessively high bird mortality. At this time, the industry had little to lose because the budworm outbreak had subsided.

Spraying Chemical Insecticides as the "Only Choice"

Through the entire period of insecticide use, a clear pattern began to take shape: when one insecticide became too risky, limitations were put on its use or it was prohibited only for another insecticide to take its place. It was obvious that there was no intention of disposing of the aerial insecticide spraying approach while it was still considered effective in securing economic interests. As the game of musical insecticide chairs was being played, further justification of the approach as a management tool continued to build. As already described, chemical insecticide spraying was called "the only option" for industry. This idea was reinforced throughout the period of spraying with both economic and scientific justification.

The basic economic (and technical) constraint to allowing an outbreak to come to completion, killing large numbers of fir and spruce, is that most forest managers operating large properties cannot salvage the dead trees before rotting takes place. When the trees are rotting, they are regarded as non-valuable (Irland and Runyon 1984, p.71):

> The fact that dead fir stumpage will be available in excess of the capacity to use it means that its true economic value to the landowner is zero. To the manager, a resource like dead and dying fir that cannot possibly be exhausted is essentially a free good. It has no economic value if it cannot be used (…) since they decline in usefulness in a few years (…) such trees have no opportunity cost to the organization.

This fact makes spraying (or some form of crop protection) a necessity if the budworm-susceptible trees are desired by the industry in large quantities. Another factor that cannot be excluded is the reduction in growth caused by budworm outbreaks, where even if mortality does not result, future value is reduced.

The spray operations themselves are constrained by another economic factor: “The high cost of spraying requires that treatment blocks be carefully selected on the basis of site quality, future growth potential of the current stands, location relative to mills, fir stocking per acre, and other considerations”(Irland and Runyon 1984, p.73). This necessary selectivity means that some amount of defoliation would have to be accepted. What came to be accepted over the course of time in the spray program as a cost-effective protection goal was to keep defoliation in the current year of balsam fir to 40% or less and red-black spruce to 50% or less (Carter and Lavigne 1984-1993).

One of the greatest economic benefits of the spray program, from the perspective of the forestry industry, is that is allowed the industry to expand. As a result of expansion, the industry came to rely on larger harvests as the norm. In the Budworm Task Force Report in 1976, Baskerville explained that (p. 201), “Neither of the current levels of productivity (industry or forest) could have been attained without crop protection. Cessation of protection now would result in large economic losses (jobs and value added) in the forest based industry over the next 50 years.” Since it is obvious that the industry was looking to expand its base over this time, spraying (or some form of crop protection) was almost a necessity. The idea of increasing the productivity of the forest by strengthening forest protection measures would continue to be a goal. As put forth by Carrow in 1995 (my emphasis),

> In 1980, the Canadian Council of Resource and Environment Ministers endorsed a national wood production target of 210 million cubic metres by the year 2000—a 35% increase in 20 years (…) *protection of the wood supply from unacceptable losses due to insects (and other agents) for the next few decades will become increasingly essential*, largely due to the escalating demand for wood and the shrinking land base to provide that wood.

Due to this expansionist philosophy, increased pressure was placed on the industry as resources became more limited over time, putting greater pressure on it to increase the intensiveness and extensiveness of the spray program. Such an operation was still deemed feasible though. All that was required was that the rate of forest harvesting be kept under the growth rate of the forest (of wood volume). The role of the budworm in reducing wood volume was simply bypassed through spraying.

Theory Leading to Practice, or the Other Way Around

The expansionist philosophy, along with the technical problem of trying to harvest dying trees before rotting and the competitive attitude towards the budworm, have been rationalized scientifically. By the 1970s, a view of the budworm-forest relationship had been established where a role was found for insecticides in the ecological functioning of the system. The view was that spruce budworm outbreaks have been known to occur in New Brunswick since at least the early 1700s and are an evolutionary part of the forest (Baskerville 1975a, Stevens and Schabas 1978). It followed that budworm populations always exist in at least endemic levels, and outbreaks are triggered by the presence of large, contiguous areas of suitable food supply (mainly balsam fir) and consecutive years of warm and dry spring weather (Baskerville 1975a). Under this model, the budworm-forest system possesses a self-regulatory mechanism with the budworm as the regulator. Consequently, humans can only compete with the budworm for the opportunity to harvest fir-spruce forests. The only way that humans can *effectively* compete with the budworm—under this model—is through slowing down the worm's effect by protection measures. Baskerville summarized the budworm's role as follows: whenever the budworm reaches epidemic levels it "destroys the host species in such a way so as to ensure the development of a new stand of the host species" (p.139).

Expanding upon this view—giving further precedence for the spray program—the content of budworm susceptible species in the spruce-fir forests of New Brunswick has been described as relatively stable for the last few hundred years, and possibly longer (Baskerville 1975, Stevens and Schabas 1978). The suggestion is that even without human intervention, these forests are subject to little change in the long term from this composition. A further suggestion is that the fir content in these forests is not changing. An important part of this logic is that *any* protection scheme will result in a more or less continuous outbreak as long as it maintains the food source (Baskerville 1975, Baskerville 1978). In the Task Force Report (1976), Baskerville made it clear that the only way of ending the outbreak and restoring ecological normalcy—as he understood it—was to let the budworm do its trick (p. 202, my emphasis):

> The persistence of the budworm outbreak is related to the forest structure and not to the method of budworm control. *Any successful crop protection program would have resulted in similar persistence*. The only way to bring about collapse of the outbreak is to allow the budworm to kill a large part of the forest (i.e. cease protection) and this would result in economic losses…

It is clear from this statement that all possible protection measures, including biological control, were considered equivalent in their effects on outbreak size, severity and frequency. The implication is that the synthetic chemical insecticides *themselves* were not responsible for the continuous outbreak (with respect to both extensiveness and severity), but it was the mere act of protection itself that caused this problem. This is an important statement because it takes away the practical rationale of changing the form of protection.

Although the role of insecticides in maintaining and enhancing production of the industry was stated clearly by Baskerville, he also made it apparent that there were some problems with this approach. His belief was that the use of insecticides over the long-term was problematic because “there is no long term policy for the use of pesticides which will result in a decreased need for them” (Baskerville 1978, p.62). He saw that the continuity of the outbreaks was due to the trees being kept alive through the sprays, leaving them prey to future budworm outbreaks. This idea was also supported by Blais (1974). Baskerville recognized that the budworm could not be completely eliminated, therefore if ripe food (“real estate” as described by Baskerville) was kept around (not harvested), the outbreak would continue for an indeterminate amount of time. Baskerville believed that there was a positive and negative effect of spraying: it was effective in keeping the industry productive and expanding, but the continuity of spraying was problematic for the public because of the non-target effects (Baskerville 1976, Baskerville 1978, Stevens and Schabas 1978). The conclusion was that industry could not sacrifice development, therefore until viable alternatives were found, spraying would have to persist. The conclusion of the Task Force in 1977 was that no viable alternatives to insecticide spraying existed, a conclusion that was reiterated until the spray program ended in 1995 (Kettela 1995, MacLean 1996).

The interpretation of the budworm-forest relationship was, however, neither crystal clear nor without debate. Academic differences of opinion that became prominent during the 1980s (Regniere and Lysyk 1995) over budworm population dynamics show that the spray program was not based on as solid a scientific foundation as may have been assumed initially (for example by Flieger, 1953; or Balch, 1952). Ironically, the different interpretations were actually derived from the same data, which were collected from studies in an area of New Brunswick called the Kedgewick Check area. This area was set aside from spraying for experimental purposes, so an understanding of budworm population dynamics could be garnered. The major differences of opinion were between the ideas of T. Royama and J.R. Blais. Royama (1984) explained that outbreaks do not necessarily leave a trace in tree rings because some are mild, and also that they have been oscillating at a frequency of 30 or 40 years for the past 200 years or so. Additionally, he believed that outbreaks are generalized phenomena that occur more or less synchronously over large geographical areas. Blais, (1985) on the other hand, believed that the number of outbreaks have been increasing (rather than systematically oscillating) in recent times due to the increasing content of its food supply—a consequence of forestry practices—and that when the food supply runs out, so does the budworm. In contrast to Royama, he believed that distinct outbreaks could occur in regions of continuous coniferous forest. Blais also believed that moth dispersal was very important for the spread of outbreaks from epicenter regions to extensive areas, but Royama viewed it as only a minor factor.

Pressure has continually been arising to more clearly determine the underlying processes in budworm-forest dynamics (Regniere and Lysyk 1995). This is not surprising considering the proposed future of forest management planning in New Brunswick—a desire for increased control over timber yield and budworm outbreaks through a computerized decision support system. If the system has an incorrect theory as part of its basis, its usefulness will be affected. The Royama model has as of late been given favour as the better interpretation of budworm population dynamics (MacLean and MacKinnon 1997).

Spraying is related to these theories in that they give indication of where, when, and how much to spray (not everything can be afforded) over the long-term. Depending on which theory is used to inform spray planners, the areas sprayed (spraying is expected to be very important in the future program, MacLean et al. 2001) may differ slightly or even greatly with regards to concentration of spray and size of the sprayed area. Examples of how this can be problematic are as follows. In the case of Royama's theory, moth dispersal is not as important as it is in Blais's model. As a result, heavy targeted spraying of moths in regions with heavy infestations may be recommended by Blais's model, while Royama would probably not advise it since he regarded dispersal as a minor factor. As well, the Blais model places more importance on the role of forest maturation: when the forest matures, if it is of the spruce-fir variety, a budworm outbreak is extremely likely. Under this line of thinking, budworm outbreaks are avoidable because forest composition can be altered to reduce the likelihood of an outbreak (Regniere and Lysyk 1995). Under the Royama model, the predator-prey scenario is more important, where there are gradual build-ups and declines of budworm populations in relation to predator numbers, parasite levels, and budworm food supply. Changing the forest composition to reduce the amount of mature balsam fir and spruce would only have a marginal effect on reducing the outbreak population under Royama's model. As a result, silviculture only has limited value and some form of external control is likely necessary in order to maintain the industry.

These examples illustrate how theory plays a part in affecting spray planning. However, despite what is uncovered through theoretical work, the same economic approach remains. The approach, as described above, that the least amount of spray be applied over the least acreage in order to achieve the goal of "efficient" prevention of mortality of economically useful tree species for wood fibre. This has been pursued to the extent possible in order allow the industry to grow.

Summary

In recapping, some themes that have been repetitive through the spray program are that: (1) damage to non-target species must be accepted, (2) the budworm is a competitor/enemy of human interests in the forest, (3) a steady flow of pulpwood must be maintained or increased, (4) insecticides are the only option in the short term, and (5) as much control as possible (maximum quantifiability and predictability) in forest management is necessary in order to meet the economic goals. Overall, the description in the last portion of this chapter has shown that there has been a great desire on the part of industry to achieve a better understanding of the budworm-forest relationship in order to exercise greater control over timber production. If industrial expansion is considered an accepted reality, then regardless of what the *governing* theory of budworm population dynamics is, curtailment of control over the insect is not really an option. As long as the insect is a limiting factor to pulpwood production and the industry desires to expand, more acute control, and theories to support such control, will be required.

Chapter Two:

Managing the Budworm Without Aerial Spraying: Other Perspectives, Dissenting Voices

Thirty years before any spray touched down on the forests of New Brunswick, forestry practices were already viewed skeptically due to an observed change in forest composition with respect to age and species diversity (Tothill 1922, Craighead 1925). At this time, human-caused changes were described as having increased the forest's susceptibility to budworm damage, and consequently, the solutions were to reverse some of the larger changes as well as to slightly modify areas of high budworm outbreak susceptibility. The recommendations were to curb what had become common practice in New Brunswick forestry: taking only the most industrially useful trees and leaving the remainder—highgrading. The recommendations came at the same time that the pulp and paper industry was beginning to dominate the forest products economy of New Brunswick, a transition that changed what trees were to be considered marketable. When the industry-government spray program (Forest Protection Limited) arrived in 1952, the focus of criticisms shifted to concerns over the lethality of the chemicals to non-target fauna, then later to the effects on human health. These were to have more of an effect on management than the criticisms of forest practices and the recommendations for silviculture.

Alternatives: Silvicultural Approaches to Budworm Control

The basic idea behind using silviculture to prevent or curtail budworm attack was articulated by Miller and Rusnock in 1993 (1993a) and was described as a *silvicultural hypothesis*. The statement went as follows: "Since forestry practices have led to increasing susceptibility and vulnerability of the affected forests, these practices should be altered so as to minimize the conditions which favour budworm damage" (p. 179).

The minimization of favourable conditions for budworm is effected, essentially, through reversing past forestry practices. Certain industrial practices over the past 200 years have been alluded to as being responsible for slowly cooking an appetizing dinner for the budworm. Where silviculture is proposed as a budworm control strategy, the "more resistant" forests of the past are mentioned (Tothill 1922, Craighead 1925, McLintock 1947) as a rationale.

Forestry practices during colonial times have been largely considered the root of New Brunswick's forest composition dilemma by researchers advocating silvicultural control. This follows from the assertion that these practices have distorted the natural balance that was present in the past (Tothill 1922, Zelazny and Veen 1997, Loo 1997). During the late 1700s to mid-1800s, there was pressure on the forests of New Brunswick as a result of the great demand by the British Empire for ship masts. Consequently, New Brunswick's forests were almost completely highgraded of large eastern white pine, which were the ideal mast specimens (McNutt 1963). By the mid-1800s, the mast trade started to die out due to changes in the shipbuilding industry. Most of New Brunswick's accessible large white pine trees had been cut by then (Gillis and Roach 1986). The transition of the industry to sawmills and the use of large spruce trees followed. The most favoured of the spruces in New Brunswick was the red spruce, which had great abundance. The practice of highgrading continued however, and the quantity of large red spruce became exhausted by the early 1900s (Zelazny and Veen 1997).

In support of the theme that biodiversity leads to more resistance from budworm outbreaks, references to greater diversity in the past forests of New Brunswick have been used (Tothill 1922, Loo 1997). Descriptions of these forests suggest a composition different than what has been seen since the earliest years of the 20th century. According to British colonial administrator, Moses H. Perley, New Brunswick's forests were full of eastern hemlock (*Tsuga canadensis*), which is present in very low abundance today (in Zelazny and Veen 1997). This species, incidentally, only experiences spruce budworm damage in very rare cases. His description of red spruce was that (p. 175), "It is so multiplied as to constitute a third part of the forests by which the Province is almost uninterruptedly covered." This constitutes a higher concentration than has been present for perhaps over a century—at least of mature red spruce. Overall, according to Zelazny and Veen, post-colonization settlers and loggers followed by the pulp and paper industry have induced a forest-wide change in frequency and abundance of a number of tree species in the Acadian forest (the forest-type that represents all of New Brunswick, except for a very small portion in the north).

Before the 1920s, the budworm was of little concern. During the 1920s however, New Brunswick foresters began to develop more apprehension over the insect. As was shown in studies by the entomologist J. D. Tothill from 1919-1922, the spruce budworm did indeed have a powerful effect on killing mature balsam fir, and when outbreaks became severe, the same was faced by white spruce. At this point, the budworm had not actively been managed to any extent; however, the pulp and paper industry was beginning to gain steam economically, and budworm outbreaks presented a serious potential problem.

As early as 1922, the idea of using silviculture to reverse *negative* trends of past forestry practices—and therefore to manage budworm outbreaks—was put forth (Tothill 1922). In his recommendations, Tothill explained that, "It will be seen that the suggestions are aimed in each case towards reestablishing Nature's balance in the forests *so that the natural checks will be* *able to prevent outbreaks of a serious kind, as they were manifestly able to do a century ago*" (my emphasis).

In order to compare the effect of increased biodiversity ("Nature's balance") on the development of budworm outbreaks, he compared an outbreak in Fredericton, New Brunswick with one in Lillooet, British Columbia[i]. In describing Fredericton, where balsam fir was in great abundance, he offered that (my emphasis), "(…) at all places, such as Fredericton, where the favoured food plant was present in *abnormally large quantities*, the natural checks were wholly incapable of suppressing the insect until it became practically starved out of existence." The contrasting explanation of Lillooet was (my emphasis), "(…) where the favoured food plants—balsam fir and Dougles fir, respectively—existed in *smaller and more natural quantities* (…) the natural checks brought about a reduction of the insect before any trees were killed and in the following year the outbreak subsided entirely, …"

Clearly, Tothill's belief was that past forests, as they were before they were affected seriously by human intervention, were more resistant to the budworm, therefore the outbreaks were not as serious. This is evident from his description of balsam fir being present in "abnormally large quantities" in Fredericton where the outbreak was more severe, whereas in Lillooet, where the outbreak was more moderate, the forest was "more natural". His recommendation, as a result, was to reduce budworm damage through re-creating past forests that he described as having more "big pine" and "big spruce", whose cutting eventually left a much greater concentration of fir.

In order to physically restore past ("natural") forest compositions, he described that pure stands of fir ought to be cut and the reproduction of spruce and pine be encouraged through the sowing of seeds of spruce and pine after every cutting operation where fir dominates. In order to boost the resistance to budworm, he also advocated the introduction of a budworm parasite, *Phyodietus*, from Lillooet. An important theme of these techniques is that a large time investment is required. A crucial requirement for his recommendations to be successful, as he indicated, was that they be undertaken swiftly (in order to allow time of establishment): "(…) the next outbreak may be expected at any time after the lapse of about thirty years…The reduction of fir is a less simple task that would be wholly impracticable were it not for the fact that there is a lapse of about thirty years in which to bring it about."

Further research by Craighead (1925) described a need for producing "thrifty and vigorous" stands in order to enhance budworm resistance. By thrifty and vigorous, it was meant that the stands be made of trees that were still growing prominently and that were free of disease. By thinning dense stands of less valuable trees, other more valuable specimens could grow into a higher quality condition. The trees intended for thinning were balsam fir as well as inferior red and white spruce, white spruce being the least favourable of the spruce due to poorer resistance to adverse conditions and less growth. He did however expect that it would be hard to keep balsam fir away, since regeneration from budworm-thinned forests tended to be balsam. According to Craighead, through logging the fir and breaking up the soil litter, a high percentage of spruce could be secured.

This is a bit different than the argument put forth by Tothill in that old stands are singled out as being weak, and more likely to be attacked. In Craighead's study, the slower growing, older balsam fir and white spruce indeed showed great degrees of damage, but the younger, faster growing trees were found to be more resistant. He also made the recognition that (p.548) "Since balsam is a very fast grower, and reproduces abundantly and under adverse conditions, it may well be encouraged for the first 30 to 40 years." Thus, he recognized the utility of balsam fir, but only within restricted age limits. Even though Craighead's recommendations are somewhat different on specifics than what Tothill suggested, the character is the same: augment the natural resistance already present in nature to control budworm defoliation.

Craighead's study came out at the time when the industry was undergoing its rapid transition to pulp and paper. A feature that marked the transition in the forest products industry was a change in the way harvesting was done. Due to the intense growth of the pulp and paper and to low pulpwood prices, large clearcuts started to come into practice in order to satisfy the supply requirements of the industry (Sandberg 1992). Before this, there is evidence to indicate that more selective methods were used. Thomas Roach (1984) has argued, for example, that woodlot farmers in northern Ontario generally refrained from clearcutting 1900 to 1930. Instead, they employed a method called "cropping". This was a sustained yield rotation that the farmers essentially arrived at universally through experience. Through the 1950s, clearcutting became much more commonplace as chainsaws, bulldozers, trucks, and skidders started to make the practice almost universal in order to most economically utilize the new technology (Peabody et al 2002).

Before the new technology would fully take over, the idea of reducing budworm damage through silviculture was re-addressed by Thomas McLintock (1947). He brought up his recommendations in the context of the *new* clearcutting practice. His recommendations covered the same points as Craighead and Tothill, but in light of the new context, he made the additional recognition that the proposed silvicultural methods would require partial cutting rather than clearcutting. Since the forest products industry had undergone significant development in New Brunswick during the 1940s (Baskerville 1995)—which included the technology just mentioned—there was greater cutting pressure (i.e. clearcutting). Although he advocated the importance of partial cutting for producing more budworm resistant stands, McLintock made the recognition that partial cutting could be economically prohibitive in certain sites, therefore calling for clearcutting. This was not an issue at the time Tothill and Craighead made their recommendations. What is apparent from this conflict (clearcutting versus partial cutting) is that the silvicultural recommendations required that some limitations on harvesting be accepted; otherwise, they could not be implemented properly. Partial cutting is a more limited strategy than clearcutting, and keeping stands vigorous means that they need to be cut while they are still young and producing volume. This ran contrary to conventional timer management practice (Hyde and Newman 1991).

Another point raised by McLintock was that the approaches only "might" have an effect on reducing budworm damage. According to McLintock, not enough research had been done to show clearly if the approaches would work on a large scale; however, he also made the confident claim that the effect of proposed recommendations on timber volume yields would be positive. He believed that there was enough scientific evidence to show that the approaches would result in an increase. In addressing the lack of practical-level research in the area, McLintock was describing the dearth of necessary financial resources that were needed. This is perhaps indicative of a lack of seriousness shown by the government (and industry) towards the recommendations for more research on silviculture made by Tothill (1922) and Craighead (1925). The fact that high timber volumes and low budworm defoliation could not be guaranteed would be brought up again—as a concern—in later criticisms of the silvicultural approaches.

During the 1940s, active budworm management was something industry had to engage in to meet their increased demands. A project was initiated during this time to test forest-wide silvicultural budworm control—essentially, Tothill, Craighead, and McLintock's suggestions put to the test. The initiative was called the Green River Project, and it started around the mid-1940s with the prime motive to study forest management in relation to budworm control (Green River Project Work Committee 1948). The focus at the time, four years before spraying, was as follows:

> Entomologists are endeavouring to increase the effectiveness of the natural control of the insect with the aid of diseases and parasites, and methods of checking outbreaks by means of aeroplane spraying are being tested, but we should at the same time take steps to improve the management of our balsam-spruce stands so that their natural resistance will be increased.

It was believed that by following such a strategy, they were pursuing the most economically efficient solution. As explained by the Committee (p. 137): "The methods used must be compatible with the ultimate objectives of sustained yield and economic production of wood." Silvicultural budworm management was regarded, at the time, as such a solution (p. 137): "(…) it would appear that the principles of management for protection from budworm are very similar to those which would be applied for obtaining the maximum economic yield…"

A crucial fact—for the purposes of this paper—is that spraying was only experimental at the time the Green River Project Work Committee put together the report referred to above. The option of "spraying away" the defoliation problem in mature spruce-fir stands, at least on a year-to-year basis, was not yet operational. At the time, forest management (i.e. silviculture) was expected to be necessary for a maximum sustained yield. What is interesting here is that the yield is regarded as limited, of course, by budworm defoliation, but also by the fact that the management scheme involved sacrificing maximum theoretical volume for the construction of a more resistant forest.

Advocacy by the Committee for forest management to control budworm outbreaks was clear. At the same time however, the authors mentioned the problems of lack of proof of effectiveness and the long period of time that would be required before results could be obtained. These were given as partial explanations for lack of action in the past, but the Committee was also clear about the "partial" truth to the excuses, essentially alluding to the fact that attempts were not made to test the ideas, or to the possibility that implementation was simply put off.

Up to the late 1940s, there was no implementation of silvicultural budworm control despite agreement by ecologists and foresters of its practical value. Since nothing had been done to prepare for the ensuing outbreak, and it was evident that the industry would be highly dependent on the susceptible species, an immediately effective, short-term solution was required. This would come in the form of aerial insecticide spraying. Amidst the initial applause of the spray program as a successful venture (Flieger 1953), the silvicultural recommendations became, at best, a potential secondary or complementary measure *if needed* (Blum and MacLean 1985, MacLean 1996).

Despite the applause of spraying, researchers did not ignore the silvicultural option. A prominent researcher on the use of silviculture for resistance to insect epidemics was S.A. Graham (1951, 1956), an American entomologist who specialized in studying forest insects, including species in Eastern Canada. In 1951, he described outbreaks of different insects in North America and how natural control could be beneficial; of course he could not avoid alluding to the fact that spraying had just recently been lauded as a successful method. Much of the message was the same as earlier arguments. One of his additions was that spraying would do nothing to change the forest conditions that favour outbreaks, but would simply prolong the ideal conditions. His reason was that spraying would kill some enemies of the target insect.

Graham did see that there was some use for insecticides, but only as an emergency measure, if other practical measures failed. He cited that silvicultural methods definitely had merit because some forest types—for example, mixed hardwood-hemlock types of the Upper Peninsula of Michigan, mixed forests of the Douglas fir region, and mixed coniferous forests on the western slope of the Rocky Mountains—never were severely injured by outbreaks.

As for the matter of insufficient evidence for the effectiveness of silviculture, he explained that such evidence was already present in the form of existing stands that suffer little damage. He also explained that past records available in the soil, tree rings, and debris could be effective for discovering the content of the past forests. In his view, through experiments, an improvement (in the context of human value) over the natural condition could potentially be discovered, but following the pattern already present in nature would suffice before this could come about.

In the context of the then-present harvesting practices and the overall scale of forestry practices, Graham also made recommendations for how to conduct management at the forest-wide level to reduce insect impact. He suggested keeping cutting units small and preventing cutting in adjacent stands in successive operations, which would promote a forest more diversified in age classes. Essentially, this suggestion is for limitations on the size of clearcuts. This style of management, according to Graham, would also help to diversify forests that naturally grow in pure stands. He explained that this would allow for a more economical long-term harvest of the desirable species, where *less* would be lost to the insect. In bringing up this point, Graham is alluding to the fact that some stands naturally reach a state of susceptibility to insect defoliation, but that it could be controlled without chemical input. He also offered that the cutting of virgin timber should occur over as long a period as possible in order to allow the second growth a long enough period of time to regenerate to a valuable state, but explained that this would be difficult because *insects would attack the stands while they were in reserve*. It is apparent that Graham believed some loss to insects would have to be accepted.

Further work by Graham (1956) contained an explanation of the role of forest insects in the “Law of Natural Compensations”. This law, as he described, was as follows: “If any plant or animal tends to dominate the locality in which it lives, either in number or influence, *environmental forces will ultimately reduce it to a lower position*” (my emphasis, p. 45). The environmental forces included all natural control factors, thus making a more diverse forest less likely to undergo serious outbreaks. He explained that some forest types that contain greater diversity are not really prone to insect outbreaks, citing tropical rainforests and a few temperate forest types as examples. Others, he described, were prone to periodic outbreaks when appropriate environmental conditions ensued. Plantations (low species diversity) were characterized as more prone to increased injury of host trees compared with natural stands.

Altogether, his assessment was that diversity could naturally hit low points from time to time, but the problem was manageable; for example, dominating balsam fir could be harvested before maturity in order to avoid budworm induced mortality. In his description, a budworm outbreak is the natural compensation for an overabundance of fir. Where "unnatural" conditions were created so as to make various stands more susceptible to outbreaks, the choice was to either sacrifice some portion of the "plantations" or to take direct action (such as spraying). In concluding, he recommended that forest managers plan operations to conform with the law of natural compensations—increasing or maintaining forest biodiversity—and also that substitutions be made for natural control factors eliminated through human interference. He mentioned that chemical treatment could be among these, but (again) that it should only be considered as an emergency measure.

Since Graham's recommendations were offered at the time when spraying had already been considered a success, they were essentially only an alternative or complement rather than the primary choice. This created a vastly different context between the recommendations made in the 1920s and the ones from the 1940s onwards. Perhaps the most important similarity was that in all instances, the management recommendations were never given a chance at implementation on a large scale. In order to find a good (and well advertised) example of such management philosophies in practice in the Canadian maritime region, one could look at the example of orchard manager A.D. Pickett.

Criticisms of the Effectiveness of Spraying

At the same time that the aerial insecticide spraying was being pronounced as a success in forestry (New Brunswick), Pickett was focusing on methods of natural control as primary and chemical insecticides as secondary in his orchards. He received international attention for his insect management approach after Rachel Carson's *Silent Spring* (1962) publicized it. Although Pickett was a manager of orchards rather than timber plantations, he still had to deal with the same dilemma of insect outbreaks. He had the same chemicals at his disposal as the forest managers in New Brunswick, which is partly why his approach was considered an exception to what was common. The philosophies that are important in silvicultural budworm management were also paramount in his approach.

He relied on biodiversity as a tool, which forced him to recognize limits to production. In an article by Norman Creighton in 1963, Pickett's views on insect management were described. His approach was to foster the natural enemies of orchard insects that were damaging to the orchard tree species. The main agents he relied on were natural and introduced enemies against the "pests", and also a very different kind of spray program. In his program (p.71), "He concentrated more on the search for 'selective' pesticides…(on) the timing of spray operations so as to *avoid harming beneficial species*; and to determine the least amount of poison that could be used to control the pest species" (my emphasis). Essentially, the insecticides were only used minimally, as the last line of defense.

Obviously, with this approach, maximum reduction of the "pest" insect cannot be achieved; rather, the focus is on *minimization* of damage to the whole ecosystem, strictly so that the system can manage itself. The following is a telling quote from Pickett (my emphasis): "We should accept the proposition that crops should be grown primarily for the purpose of satisfying man's food requirements and not as a means of making particular human activities commercially profitable *regardless of the overall effect on human welfare*" (p.71). This is an example of the fact that by focusing on "natural" management, limits to consumption (harvesting) must be accepted.

Another important idea coming out of Pickett's approach is an initial sacrifice in the short term for the sake of long-term stability. In reference to the survival of natural enemies of "pests" Pickett explains (p.72):

> You can't shift over night and then expect miracles. These animals you have been killing off for twenty-five years are not sitting on a rail fence waiting to come back. It takes years to get some of them back. Some of them we have to import.

Pickett's approach provides an interesting contrast to the approach taken in New Brunswick to manage the budworm. This undoubtedly made it an ideal comparison for Rachel Carson in *Silent Spring*, where insecticide spraying in New Brunswick was criticized and Pickett's integrated approach was praised.

As aerial insecticide spraying became the budworm method of choice in New Brunswick, both *poor* forest management and *poor* consideration of other fauna as well as human health became concerns. The Nova Scotia entomologist and forester, Lloyd Hawboldt, provided some of the most vehement opposition to this *poor* forest management method. Although his management ideas were focused on maintaining high industrial productivity, he was mainly concerned with the long-term, which perhaps allowed him to rationally support silvicultural management over spraying for controlling the budworm. He advocated conducting a combination of salvage and pre-salvage operations in extremely vulnerable areas and to control the composition of the forest so as to prevent conditions that promote budworm outbreaks (Sandberg and Clancy 2000).

Since Hawboldt was a Nova Scotia forester, his perspective was certainly different from a New Brunswick forester at the same time; he was arguing to prevent spraying from being initiated rather than to get rid of it. Very similar to Pickett, he offered a minimalist approach to spraying (Sandberg and Clancy 2000, p.127):

> In the case of a valuable stand of timber which cannot be harvested within the next few years, the pest population may be kept down enough by spraying to protect the stand until operations are underway. Such action has merit. However, in the case of mature and overmature stands which cannot be harvested within another twenty or thirty years, what possible assurance could there be for success? Within that time spruce budworm could be expected to return to such a susceptible forest, perhaps very quickly.

In disapproval of continual insecticide use, Hawboldt explained that, “Ecologists have been aware for many years that the use of pesticides prolong the need to continue their use. The annual application of insecticides to preserve large forest areas from the spruce budworm prolongs outbreaks and presents a serious hazard to environmental quality.” Hawboldt did not believe that the spray approach had any merit as a long-term or large-scale solution. Although Baskerville (1978) and Blais (1974) also warned of the danger of continual insecticide use (as described in the previous chapter), they did not go so far as Hawboldt in that they still saw the necessity of spraying for economic reasons while Hawboldt saw it as an economic mistake because it caused problems in the long-term.

By the 1960s, the initial silvicultural budworm management ideas were over 40 years old and much had been added since, but implementation still never resulted. The criticisms of forestry practices and the logic of spraying, it can be said, had little impact overall on affecting the aerial insecticide spray approach. Questions about the importance of biodiversity, long-term budworm management planning, and limits to harvesting were never really answered. The underlying philosophy of silvicultural recommendations actually changed little in character over the period. “…they reflect the basic concepts of good silvicultural practice: short rotation and intensive exploitation of balsam fir; separation of susceptible types into small compartments broken up by areas of non-susceptible forest and younger age classes; and the encouragement of other species” (MacDonald 1968, p. 35).

One piece of reasoning that was very important as a criticism of both past forestry practices as well as the aerial insecticide spray program is that the extensiveness and severity of the outbreaks had been increasing. Research by J. R. Blais (1983) demonstrated that an increase in frequency, extensiveness and severity have all been apparent in Eastern Canada over the past 200 – 300 years with few exceptions. This idea came to be associated with supportive arguments for silviculture over spraying (Miller and Rusnock 1993a). In the nine regions tested, he discovered a general trend of greater periodicity of outbreaks in the 20th century. He described an increase in area of outbreak size in eastern Canada (Ontario, Quebec and the Maritimes) from 10 million hectares in the 1910s to 25 million hectares in 1940s to 55 million hectares in the 1970s. With regards to severity, his finding was that the percentage of mortality of fir and white spruce was greatest in the outbreak of the 1970s. The increases correlated with human interference—clearcutting, fire control, application of insecticides in the areas, and abandonment of marginal farmlands—but one factor, birch dieback, was considered natural.

Ironically, although Blais offered an apparent critique of forestry practices, mentioning that a change in forest composition towards more resistant types would probably be an effective long-term plan, he argued that it was not economically feasible to limit industry in this way. He questioned, "(…) is this approach realistic? The forestry industry in eastern Canada is largely based on the exploitation of softwoods…" Blais suggested that forest management caused the problem to become worse, but he also brought in this "economic reality" that makes spraying necessary. In an earlier piece (1974), Blais described how spraying prevented "the natural course of events"—exhaustion of the budworm's food source—making the prospect of another outbreak greater and closer in sequence. He added that the potential negative consequences did not justify a policy change. "For the time being, chemical treatment of spruce-fir stands as a protection against budworm in Eastern Canada may well be considered an indispensable forest management practice at least for some regions" (p. 20). The economic necessity of spraying was due to a demand for fibre that spraying fulfilled. By making this suggestion after first mentioning how forestry practices have likely caused the outbreaks to become worse, he is addressing the gap between the two ideas. Spraying of chemical insecticides was considered an acceptable risk.

"Viability" of Silvicultural and Biological Control Strategies

As described in the previous chapter, spraying continued to be a contentious issue through the 1980s. During this time, Canada and the United States formed a cooperative unit, CANUSA, to perform research on the spruce budworm and different control options. Silviculture was brought back into the picture as a potential tool (Sanders et al. 1985). Even by this time, it was still described as only a “conceptual” idea (Blum and MacLean 1985). It apparently had merit on only the qualitative rather than quantitative level. Blum and MacLean describe that “For real progress in managing budworm infestations, procedures must be defined in terms of forest type, timing, location, area involved, and their projected results” (p. 265). Knowledge on the effectiveness of silvicultural control was also described as fragmented.

Over a decade later, the feeling was much the same. David MacLean (1996) described how, in reference to silvicultural tactics (p. 401), “…the problem with all of these references is that rarely, if ever, can recommendations be quantified in terms of their expected reduction in vulnerability; most recommendations are really working hypotheses rather than proven concepts. Treatments are also insufficiently defined with respect to type, timing, location and amount.” This makes it seem as if little further knowledge had been developed since silvicultural control ideas were first proposed in the 1920s.

This low status on the knowledge of silviculture as a budworm management technique may sound ironic at first, considering that the research motive at the beginning of the Green River Project in the 1940s was to develop a better understanding of how silviculture could be used to control spruce budworm populations at the forest level (Green River Project Work Committee 1948). As mentioned further above, the project was put forth with the idea in mind that it *was* feasible at the practical level. This raises an interesting point. What was the value of the Green River Project all those decades earlier if the state of knowledge on silvicultural control methods was still considered inadequate by the 1990s? The concerns over efficacy of silvicultural control should have at least been somewhat covered from analysis of the Green River studies. Since Blum and MacLean (1985) did not even mention these studies in their chapter, “Potential Silviculture, Harvesting and Salvage Practices in Eastern North America”, it is reasonable to conclude that the studies at Green River were simply abandoned or regarded as insignificant. This is consistent with the opinions above on the viability of silvicultural control mentioned above.

Another factor that has certainly had some effect on the perception of viability of silvicultural control methods is the mobility of the budworm. Greenbank (1980) performed a detail study on the movement of budworm moths using radar. The dispersal capabilities of the moths was shown to be on the order of hundreds of kilometers. Baskerville’s assertion (1995) that aerial spraying in the past has had the effect of chasing the budworm around the province, as well as the recognition of foresters in Nova Scotia that dispersal of moths from New Brunswick may have exacerbated the outbreak in Cape Breton (Sandberg and Clancy 2000) certainly present some problem for the effectiveness of silvicultural control methods. If large flocks of moths are driven away by spray residue from the most vulnerable areas (continuous areas of mature balsam fir already suffering from defoliation), into areas of typically low susceptibility, the usefulness of silviculture is certainly diminished. Small areas devoid of spray may suddenly become vulnerable to budworm if surrounded by sprayed areas even if silvicultural measures were undertaken to try and prevent such an event from taking place.

An option that has often been associated with silvicultural control was biological control (Tothill 1922, Kemp and Simmons 1978). Some researchers placed great importance on this link. A couple of examples to illustrate this are as follows. An egg parasite of the budworm, *Trichogramma minutum*, was shown to increase in population size when the diversity of tree species in the area was increased (Kemp and Simmons 1978). It was noted that species such as sugar maple, yellow birch, paper birch, red maple, big-tooth aspen, and red spruce are all important for establishing the diversity required for *T. minutum* populations to flourish. The reason for this was that they provided alternate host habitats. The same relationship was present between birds and budworm. As was observed by Tothill in 1922, birds had a very important effect in suppression of severe outbreaks in British Columbia where diversity of insectivorous bird habitat was high; however, in Fredericton where the bird habitat was limited, so was the suppression of budworm outbreaks.

The common ground between silvicultural and biological control is that the implementation of both requires a long-term focus: both require a relatively extensive period of time to take effect, silvicultural control more so. Miller and Varty (1975) detailed the difficulties with industrial-scale use of biological control. They pointed out that there were many problems encountered in attempts to introduce exotic parasites—entities that were hoped to offer a quick solution to budworm outbreaks. All the attempts ended in a failed establishment of the exotic. Native parasites, predators and diseases fared no better for control of budworm. Budworm populations would reach epidemic levels despite the presence of these natural control factors. The prospects for using behavioral disruptors (the insects' own chemical regulators) were also considered only mediocre. Altogether, the option of biological control was cast in the shadow of doubt because of a lack of satisfactory[ii] results on its effectiveness. It seems that biological control suffered the same problems as silviculture with regards to implementation. It was always described as unready or insufficient (Marshall 1975, Baskerville 1977).

Using silvicultural methods to manage budworm outbreaks was mentioned again recently, but this time in a different character; the context was efficiency of industrial operations (Needham et al 1999). The effectiveness of biological control factors in controlling budworm populations was linked to the silvicultural methods. In the study, Needham et al. demonstrated that hardwood content in otherwise pure stands of mature balsam fir had a positive effect on overall balsam fir volume when outbreaks are severe. The reason for this, which parallels thoughts voiced in the past, was that the increased diversity in the stands allowed for a greater diversity of natural enemies of the budworm (Kemp and Simmons 1978, Crawford 1985)—the specific reasons were not known. The idea was that stand management that incorporates hardwood content could be used to minimize losses where there are severe and frequent outbreaks. Although the study actually did contain some quantified results, its usefulness was deemed to be dependent on the forest structure and composition, the options available, and the *philosophy* under which the forest is managed. The conclusion was that the results of the study applied to specific and local mixed management cases only. Since industrial forestry in New Brunswick is mainly reliant on softwood volume (not mixed), it is unlikely that this approach conforms to its *philosophy* of management. As well, the approach was *not* recommended for anything beyond local management cases. Thus, the forest-wide quantitative results desired by New Brunswick's industry were still not available.

Ironically, even though supporters of the spray program have often called silvicultural control unproven and insufficient, the spray program itself has also undergone the same criticism. A report by the National Research Council of Canada (1977) gave very harsh criticism of the method in practice (p. 3-4):

> The actual operational control program is so complex and chaotic that, except in the crudest sense, we have no knowledge of how much spray will actually reach the spruce budworm or where the remainder will lodge in any given operation (…) I hope that the stupidities, deliberate or otherwise, which have plagued the use of fenitrothion will be a sufficient object lesson to all so that they will not be repeated.

In the response to the report, I. W. Varty (Canadian Forest Service scientist) explained the difficulty that arose in trying to avoid unintended side effects of spraying (Varty 1977). Varty described that (p.3),

> Forest spray operations do not lend themselves readily to research manipulation, and it cannot be expected that operators can subordinate their prime responsibility to serving research needs. The Spray airstrip has a pressing schedule in May-June, and it is costly to set aside spray planes, pilots, mechanics, mixing tanks and materials to await the design of the experimenter and the whim of the weather.

Basically, as can be interpreted from Varty's statement, the economic needs override the incentive to come up with a completed environmental impact assessment prior to spraying. This rather heated interchange between the National Research Council and Varty was described by Miller and Rusnock (1993b) in an article appropriately titled, "The ironical role of science in policymaking: the case of the spruce budworm."

Non-Target Damage Caused by Spraying

Criticisms of forest management and the adverse effects of the protection spraying method on forest structure were only part of the overall criticism. Another, and perhaps much more poignant part, was focused on the sprays themselves and how they affected fauna and human health. During the 1960s, the effects of spraying on non-target organisms became a major concern. Rachel Carson's *Silent Spring* was very important as a catalyst in bringing recognition to some dangers presented by insecticide spraying. These concerns, unlike the above ones, *did* actually have some effect on insecticide spraying, at least in terms of leading to restrictions on where spraying could be done and what chemicals (to some extent) were sprayed; they did not have an effect on the methodology itself or the logic behind it.

In Carson's book, the dangers of insecticides were described vividly and an entire chapter—Rivers of Death— was devoted to describing the effects of DDT on New Brunswick's Mirimachi River. In this chapter, the death of salmon—very precious economically in New Brunswick—during the first few years of insecticide spraying was described in detail, where the death of their food source was the problem. Bird death was also mentioned as being extremely high. *Silent Spring* is regarded as a landmark in the environmental movement, galvanizing a lot of worldwide attention towards chemicals used by industry and what the negative effects are on natural systems and human health. After its publication, there was heavy lobbying for more environmental regulations in North America, which was assisted by a lot of media coverage. Such attention, especially with an anecdote specific to New Brunswick and DDT, no doubt, had an effect in pushing regulations forward in New Brunswick, and DDT was eventually declared prohibited (Kettela 1995).

Even after the prohibition of DDT, the scrutiny of insecticides continued. A couple of court cases arose in the 1970s that drew attention from the government, and regulation was soon to follow. In one instance, blueberry growers, Bridges Brothers Ltd. (1972) took issue with the death of pollinating bees, because of damage to the crop. The blueberry growers, Bridges Brothers Ltd., were seriously dismayed by the loss of their crop over the period of 1970-1971, and claimed that the spraying of fenitrothion resulted in severe damages to their crop over this two-year period. They assessed a loss of $1,331,693.14. By 1976, they were awarded for damages adding to $58,500 plus costs (in, Karen Lie 1980). This case was instrumental in the eventual prohibition of spraying within 3.2 km of blueberry fields, as described in the previous chapter. This was significant because the spray program previously had very few restrictions placed upon it.

Another case, Friesen et al. (1978) pitted a family of New Brunswick landowners against the company Forest Protection Limited for what they regarded as careless spraying of their property. The case of Friesen et al. versus Forest Protection Limited, since Friesen et al. won, may also have been instrumental in leading to restrictions (Friesen 1978). In the case, the Friesen property was sprayed while they (mother, father and son) were outside and the son suffered a severe asthma attack. They claimed that Forest Protection Limited trespassed and caused personal injuries, bringing to attention concerns over spraying being conducted too close to habitations. In 1977, forest protection was removed from 40% of the forest, when a mile "setback" from habitations was decreed. Clearly, in the Friesen case and the ensuing regulation, the risk of spraying the insecticide (fenitrothion) was deemed too great to warrant its use near habitations, despite the economic losses to the industry.

One fact that was made clear in the prohibition of spraying near habitations was that something that was previously justified as an acceptable risk became an unacceptable one. The Friesen case is actually only one example of accidents that were relatively frequent. Due to the nature of the aerial spraying methodology, it was difficult to avoid various accidental spraying incidents. As spray plane pilot Rick Shellallah comments (Deveaux 1983, p. 3),

> You don't spend much time looking at the ground beneath you. You can't. You are looking ahead for obstructions, trees, wires…You have simply a switch in the cockpit; someone is above you in the air, higher than you, you are coming up onto the block…they say 'booms on' you throw the switch, and you begin spraying. And when they say 'booms off', you throw the switch again and stop spraying. You can't see people in the woods…you can't see people under those trees if they are in there…It's up to the spotter airplanes to tell you that there are people ahead of you. If they don't see them, no one sees them.

Shellallah also explains another large problem with spraying: that of spray drift. In his words (p. 5):

> And you can see spray coming off the airplane, very very beautiful almost. It's almost like a lesson in aerodynamics, because you can see the vortices created by the aircraft itself. And it would hang in the air in a very still warm evening. And we sprayed the block, and went away to get another load and come back. And when we came back, our first block was still in the air, laid out like corn rows, but it was downwind about 30 miles or so, just moving into the city of Fredericton.

Likely the most infamous debate to have arisen on insecticide spraying in New Brunswick was the one over human health. Parents of children affected by a rare disease called Reye's syndrome (and others who sympathized) banded together to form the Concerned Parents Group (CPG), in order to draw attention to possible human health effects from the spray. Numerous court battles ensued (Miller 1993), and much negative attention was drawn to the issue of environmental toxicity. Fenitrothion was finally banned in 1998—but not *explicitly* for its effects on humans. The reason was deemed to be that the mortality to forest songbirds was far too great.

The disease was first noticed in New Brunswick in the early 1970s. A few cases of the disease were enough for parents of victims to make a connection between the disease and forest spraying in their areas. Through the initiative of the CPG, scientific tests were done which demonstrated an apparent link between the disease and a component of the fenitrothion spray formulation. Through the next several years, there were a series of court cases with the CPG pitted against FPL; expert panels were formed to assess the possible link between spraying and the disease and much media attention was drawn towards the issue (Miller 1993).

In the spring of 1977, the CPG laid 31 charges against FPL for alleged effects of the 1976 spray program. They cited violations of both the Federal Fisheries Act and the Pest Control Products Act. FPL used its Crown status as a defense to make them free from liability, but this defense saved them only from violations of the Pest Control Products Act (in Karen Lie, 1980).

The end result of the CPG's efforts—the group slowly disbanded in the early 1980s—was a lot of media attention, but no absolute prohibition of fenitrothion spraying in New Brunswick. They were probably effective, however, in helping to prevent habitations from being sprayed as their allegations coincided with the Friesen vs. FPL case. Incidentally, fenitrothion was banned in Nova Scotia because the government was convinced (through another great public battle) that the chemical both *did* have an effect on increasing the incidence of Reye's Syndrome in New Brunswick and that the efficacy of the spray approach was questionable (May 1982).

Although the thrust of the arguments that the Concerned Parents Group gave was about problems with sprays affecting human health, they also offered criticism on the efficacy of the approach in general. In these criticisms, they echoed arguments against spray efficacy when they described how eight of the other provinces (minus Saskatchewan) had not taken the step of insecticide spraying to the extent that it had been carried on in New Brunswick (Concerned Parents Group, Inc. 1977). The view stated was (p. 15, my emphasis):

> We believe that the government of New Brunswick should recognize the wisdom of the decisions taken in other provinces. It must be recognized, of course, that the situation in each province is different. These differences, however, cannot change the fact that the spray program is *not effective in maintaining the economic value of the forest*.

A further suggestion was made that the practice of insecticide spraying could only be considered useful for maximizing short-term profits. Following from this assertion was what could be considered the overarching philosophy—the bottom line—of the Concerned Parents Group (p.17): "…even if the program of spraying were protecting, marginally at least, the forest in economic terms, the program still has to be stopped for environmental and above all for health reasons." In other words, if spraying was required to maintain the yield levels desired by the industry, considering the environmental and human health effects, the excess volume was not worth the risk.

Such claims about the danger of sprays and their suspect usefulness for long-term forest management have received negative attention as basically uninformed scientific opinions. In the spirit of this criticism, Baskerville (1995) described how the public tended to use scientific observations out of context, that they offered over-simple solutions, and that they used science selectively. It is important to bring up this disregard because the Concerned Parents Group, although they received a lot of media attention (Miller 1993, Baskerville 1995), never was able to bring about a halt to the spraying of fenitrothion. Criticisms of their approach, in which they allegedly played to the media to gain more attention, resulted in their opinions being considered as emotional rather than rational by those who made the final decisions on forest management (Miller 1993).

Overall, the concerns over human health—and financial losses as in the case of Bridges Brothers Ltd.—had an effect in that concessions were made in terms of total area *officially* sprayed, but the chemicals themselves changed very little in response to such concerns. The concessions also only represented a minority portion of the forest, although it was claimed that the industry suffered grievous damage as a result (Kettela 1995, Baskerville 1995). The concerns over "accidental spraying", an event sometimes very hard to control as described by pilot Rick Shellallah above, continued despite the concessions. The accomplishments of the concessions can therefore be called minor, especially when compared to those in Nova Scotia, where spraying of synthetic chemical insecticides was completely prevented (May 1982, Restino 1993, Sandberg and Clancy in press). The actual prohibition of fenitrothion in 1998 was perhaps the largest accomplishment—from the perspective of those concerned for human health—even though the banning was not directly attributed to the concerns for human health but to an irreconcilable loss of bird life.

Summary

The concerns over the loss of biodiversity and structural diversity in the forests from spraying and forestry practices—the hypothesized consequence being a weakening of the forest's natural control mechanisms—were never seriously resolved at any level. If these concerns were actually accepted as legitimate by the industry, then they would likely have resulted in a shift in "pest" control strategies and in forest management in general. Greater efficiencies in spray technology and more attentiveness by spray pilots to ensure less accidental spraying are not relevant advances towards addressing these concerns. Concerns over human and faunal health were perhaps able to make an impact while these other concerns were not because human and faunal health required only a *definition* of acceptable risk rather than a *redefinition* of forestry practices. Curtailment is much simpler than change. The conventional economic rules for efficient insect control (see previous chapter) could remain under a simple curtailment strategy.

A summary of the themes of this chapter, which are criticisms of the logic and justifications presented in the previous chapter, are as follows: (1) human influence, largely protection spraying and clearcutting, created the problem of massive and severe budworm outbreaks, so they need to be curtailed; (2) the biodiversity of a forest strengthens its ability to resist damage from budworm, thus biodiversity needs to be actively restored rather than diminished; (3) time is required to restore the forest's strength, thus forest management should be focused on making long-term silvicultural and biological investments; (4) spraying causes a need for more of the same, thus it is an ineffective and unsustainable measure in the long-term; and, (5) chemical insecticides are too dangerous to faunal and human health to be justified. As shall be explained in the proceeding and final chapter, "A Historical Assessment of the New Spruce Budworm Spray Regime", these criticisms will have to be weighed against an apparently integrated new approach, which is professed as being free of any synthetic chemical insecticides.

Chapter Three:
An Historical assessment of the new spruce budworm spray regime

The purposes of this chapter are to identify how a proposed new spruce budworm management strategy relates to criticisms of the past program, and to explore what new criticisms may arise as a result of unresolved debates. These will be described so that a comparison can be made between the proposed program and the past one. The extent to which the criticisms of the past program (as identified at the close of the preceding chapter) apply to the new one will be used as a measure to identify to what extent past criticisms have been resolved in the design of the proposed approach. To assess how the proposed program has developed from an environmental standpoint—in terms of its responsiveness to past criticisms—the historical basis of the new program and its likely implications will first be described. The critical examination follows.

New Spray Program: Historical Roots and Present Expressions

The first spray program in New Brunswick lasted from 1952 until 1993, and all commercial spraying on crown lands halted by 1995. The program was based on the use of chemical insecticides, sprayed aerially in order to suppress budworm populations enough to allow the industry to increase harvesting over time. Non-target damage was accepted as necessary in order to achieve such targets and the budworm was clearly seen as a competitor with humans for the supply of pulpwood. As well, chemical insecticides were seen as the only short-term option because nothing else was so effective at reducing budworm numbers in somewhat of a predictable manner. Other options such as the use of natural and exotic enemies and silvicultural manipulation were not considered efficacious or predictable enough.

Since the budworm has been at very low endemic levels for quite some time—the "need" for protection gone—there has been a lot of time for reflection of the past program, but a severe outbreak is expected very soon (Smith 1998, MacLean 1996, MacLean 2001). This prediction is made based on the pattern of past outbreaks in the province. Since the outbreak has subsided[iii], there has been pressure on the industry for improved environmental standards (Carrow 1995). There has been a much more public focus on sustainable forest management globally since the Rio Earth Summit of 1992. Environmental certification is now something that forest products industries globally need to consider due to an increased consumer demand for changes to past forestry practices (Canadian Council of Forest Ministers 2000). Much of this pressure has occurred while the spray programme was at halt. The proposed spruce budworm management approach has been in development during this time, so somewhat of an increase in awareness of the past criticisms may be expected.

The new program, the main component being the Spruce Budworm Decision Support System (SBDSS), has been in development, in a sense, for nearly three decades. From 1973-1976, a team of researchers from New Brunswick, British Columbia, and internationally did an ecosystem-modeling case study on the budworm "problem" in New Brunswick (Holling 1978). The project (referred to below as "Holling's study" or "Holling's model") was designed to create a framework for decision-making through a consideration of relevant ecological, economic and, social criteria. The goals were twofold. The primary was to try and characterize sets of alternative policies relevant not only to the situation in New Brunswick, but to natural resource management worldwide, and the secondary goal was to come up with a general assessment of the then-present "state-of the art" in ecosystem modeling and policy design.

The model was somewhat constrained—in theory— from being an ideal framework for decision-making specifically on the New Brunswick case. The study was simply an example used to test a resource management decision-making model. The exercise was supposed to generate a model with usability for a "constellation of problems occurring in various regions in various nations" (Holling 1978, p.145). In order to fit such a build, the model had to give *primary* consideration to resource-related and ecological criteria instead of socioeconomic criteria, which were argued as being much more regionally specific in nature. Socioeconomic criteria were left out until the policy-evaluation stage of the model.

Since the Holling model was a major historical precursor to the proposed SBDSS, it is useful to describe its basis. There are some important similarities—which will come into focus as the proposed program is described further ahead. Since generalizability was emphasized as an important objective in Holling's study, the model had to retain some measure of simplicity. The ecological components of the model—the primary part of the overall decision-making model—were as follows. The model's focus was on the most important tree species with regards to the budworm problem from the point of view of the industry, which was balsam fir. The main variables considered were the age of the trees, the age of the foliage (2 choices: new or older than one year), the budworm, and the weather pattern. These variables were measured over a spatial extent that covered an area reflective of the moth's dispersal capability (50,000 square km) and the time duration that would encompass a minimum of two outbreak cycles (150 years). Natural enemies were considered important, but were left out as a major variable.

Leaving out ecological variables such as different tree species and natural enemies definitely simplified the model. Within these limitations, the model was regarded as having "considerable accuracy" when simulations apparently reproduced budworm outbreak events that occurred between 1953 and 1975 (Holling 1978, p. 157). In order to emphasize the limitations, Holling acknowledged that the analysis, or any like it, was only an abstraction of reality. He described that what is left out of the modeling exercise at the initial stage of the analysis cannot be ignored at the policy evaluation stage, where socioeconomic factors—however complex they may be—also had to be included. In this part of Holling's model, different objectives (on a spectrum from purely economic to purely environmental) were linked to different policies on forest protection, which were based on the results of the first part of the analysis. Leaving out socioeconomic factors in the primary part of the analysis was crucial for increasing the simplification and transferability of the model. Through this exclusion, the general societal dislike of insecticide spraying and alternative views of forest management, including management for alternative forest-based markets or for non-market uses and relationships, were avoided as variables.

The time that Holling's study came out was somewhat of a turning point for the industry. Computers were just entering into the picture as a management tool. With the advance in computer technology came more ambitious resource managers. The prospect of knowing the volumes of wood available far into the future (decades) was suddenly made into a technological reality[iv]. The new SBDSS has its historical roots in the computerized resource modeling approaches that began to arrive in the 1970s.

Baskerville made an interesting observation about forestry in the 1960s related to this point on technology. He explained that because computers were not readily available during the 1960s to perform complex calculations, the industry was constrained in figuring out how to efficiently manage the resource. He gave a detailed summary of the development of computer modeling systems for simulating forest and budworm dynamics, and strongly advocated for their integration into a model that would dictate more efficient harvesting and spraying over the long-term (Baskerville 1995). He described the evolution of timber volume predictions and harvest planning, where he criticized the traditional approach, which consisted of aerial surveys followed by "simplistic" (p. 54) mathematical calculations. He considered the development of the new technology and modeling approaches (referring to Holling's model) as a positive step because he saw in it the potential for far more efficient forest management over the long-term in terms of wood volume. The *lack of efficiency* in the past was one of the lamentations of Baskerville; he complained about projected supply problems that were caused by a previous lack of spatial and temporal considerations by forest managers (Baskerville 1995).

The system that is currently in readiness for the next outbreak, the SBDSS, is considered a redesign of the past approach. Thomas Erdle put the rationale for the new system forth in 1989. In comparing the proposed approach to the past one, Erdle described how the proposed approach was a vast improvement with respect to efficiency. The supposition was that the new approach offered a much more exact identification of the future wood supply benefits of different levels of protection (p. 127, my emphasis):

> The two approaches are fundamentally different in their ability to answer two key questions: (1) what are the wood supply benefits of a specific protection program? And (2) what is the most *efficient* sequence in which to order stands for protection priority? The proposed approach provides answers to both questions; the current approach answers neither.

Erdle's comparison between the past and proposed approach make it clear that the proposed approach's main selling point is an increase in *efficiency* in timber production over the long-term.

The SBDSS has been designed as a province-wide tool, where expected harvest volumes are derived from a combination of forest growth measurements and expected losses due to the budworm when forest protection is included. All information is plugged into databases and analytical computer models. One component of the SBDSS, the Protection Planning System, allows the user to simulate different protection scenarios, i.e. predicted levels of defoliation resulting from different quantities of spraying and different protection methods. This is the main interactive component of the system. The computer model bases the consequences upon the accepted theoretical understanding of budworm population dynamics and forest growth dynamics, and also on efficacy of past protection programs. Spatial planning is also considered much more advanced in the proposed system due to the expected forest-wide use of innovative (compared with the past) Geographic Information Systems (GIS) technology (MacLean et al 2001).

The system is updated with data on both a yearly and a five-year basis. Data for the previous year's defoliation as well as the protection priorities and predictions for the following spray season are updated on a yearly basis. Five-year updates correlate to the requirements of Crown leaseholders to update their management plans on a five-year basis. Five-year tasks for SBDSS data inputs include updating the predicted harvesting and defoliation impacts to the stand and forest.

It is important to keep in mind that the SBDSS is a system designed to act as an information aid. Through it, a forest manager can get a sense of what the economic benefits and costs are of deciding to spray or deciding to refrain from spraying. The idea is that correct use of the system will lead to less waste of sprays and to an avoidance of over-harvesting. As described by David MacLean, (2002, pers. comm.) the SBDSS is more selective than the past approach. Overall he considers that less area will be treated, also alluding to the fact that too much was sprayed in the past. By itself though, the system will not make choices. The manager must still weigh the options (put in terms of economic benefits and costs) quantified by the system.

As described in chapter one, the understanding of budworm population dynamics has never been regarded as complete—more specifically it has been regarded as a mystery[v]. Of the two competing models considered lately (Royama's and Blais's contrasting ideas as described at the end of the first chapter), Royama's has very recently been given favour as a closer approximation of budworm behavior (MacLean et al 2001, MacLean and MacKinnon 1997). This very recent adoption raises the point that perhaps the system is not as ready as is desired. In some words of apprehension, Ian Taviss (forester with J.D. Irving Ltd.) commented, "The decision support had better be done before we hit the field. At that point in time, we should not be making the tradeoffs. Now is the time to be looking at the different scenarios" (Smith 1998, p.47). The adoption of one idea over another can certainly have large implications. The differences in management that could result from adoption of one or the other of these theories have already been described in the identified section.

The idea that the understanding of budworm-forest population dynamics has been unclear is made apparent by the fact that long-term forecasts are not given much weight and neither are predictions of exactly when an outbreak may arise. Pheromone counts can give a 2-3-year warning, but this is currently the limit on resolution (MacLean 2002, pers. comm.). The SBDSS is a "what if" system. When an outbreak starts, it gives some indication as to how the outbreak may progress depending on the stand composition, the weather, and the state of the outbreak. On a forest-wide level, there are great expectations on the system to be accurate, and an acceptable level of accuracy has been experimentally shown in the past (MacLean 1996, MacLean et al 2001); however, the relative precision on a stand level is not considered to be so significant. Despite this, government (DNRE), and private companies (Forest Protection Limited for example) have recognized the predictive power of the system through supporting it with funding (MacLean 2002, pers. comm.).

Clearly, the industry sees the potential for the new program to offer great improvements over the past program from their point of view. As described by Guy Smith in *Canadian Forest Industries* (1998, p.43), "The natural, long-awaited collapse of budworm populations has finally relegated those large-scale programs of the past to a chapter of forest protection history." The long-awaited collapse occurred some time between the mid 1980s and the early 1990s. The key word may be “finally”. The future forest protection program is said to be more targeted and involve more small-scale operations (Smith 1998, MacLean et al. 2001).

The technology of forest protection has advanced greatly, and the precision of protection operations is expected to be much higher than in the past, but the proposed protection approach is largely similar to the past one in intent. In both cases, protection priorities are established (MacLean et al 2001) and in both cases they are based on chosen limitations on defoliation of valuable trees: 60% for balsam fir and 50% for red and black spruce (Carter and Lavigne 1984-1993, MacLean et al 2001). As well, in both past and present, the goal has been/is to maintain or increase harvesting levels in order to keep the industry competitive economically.

Again, the benefit of the proposed approach is the increase in efficiency in long-term timber harvesting, and making maximization of timber yields as cost-effective as possible. In the past, the approach was to use aerial hazard maps to identify priority spray areas, but now priority areas are decided largely based on past data on outbreaks, forest landscape information provided through GIS technology, and future economic values of stands and their susceptibilities to outbreaks as predicted through the SBDSS. There was (and still is) the “problem” of not being able to spray everything due largely to cost of an extensive spray program, environmental dangers and the limited time period during which spraying is effective. Therefore, during times of heavy defoliation, higher priority stands may receive protection at the cost of refraining from protecting on other stands. Priority, of course, is dependent on the value of the stand to the industry in its management plan and on the imminent danger posed by the budworm.

As described by Erdle (1989), one of the ways the approaches differ is in the capacity to define the quantified effects of different levels of insecticide spraying. Another apparent improvement is that the proposed approach has *some* capacity to evaluate different protection strategies. Five different strategies—that have changed very little over the 50 years of spraying—have been identified (MacLean et al 2001): (1) spraying to prevent defoliation, (2) conducting salvage harvesting of dead trees in the 3 to 5-year period when still usable, (3) altering species composition by planting non-susceptible trees or low susceptibility species, (4) using precommercial thinning at the stand level or harvest planning at the landscape level to reduce the most susceptible trees, or (5) doing nothing and accepting the results.

Evidently, there is some indication that strategies that were neglected in the past will have a place in the proposed strategy. MacLean (1996) described that spraying will still be used "judiciously, but not everywhere" (p.402), and that silvicultural control methods will be used (or at the very least considered) in the proposed strategy. The expectation is that the other strategies will be found useful in some of the non-priority areas. If the priority areas are chosen more precisely, and spraying is indeed reduced overall, there is certainly a possibility that other measures could be used to augment the resistance of susceptible stands over the long-term, or to minimize losses (in the case of salvaging). It is difficult, however, to judge how much other strategies have been incorporated into the proposed strategy because they have been consistently referred to as only hypothetically understood at the quantitative level (Blum and MacLean 1984, MacLean 1996).

In reference to current silviculture for budworm control, MacLean (2002, pers. comm.) described how it is a proactive approach that some companies are taking the initiative with (J.D Irving Ltd. as the example). The Decision Support System, in his opinion, quantifies how well silviculture is being done on a spatial basis. The meaning of this is that the system can quantify the economic benefits that an already established silvicultural program has led to in a particular area, and that value can be compared to the value of other stands where different approaches (including spraying) have been tried. The predicted costs of protecting such a stand could also be compared to others. With appropriate silviculture, he explained, one can get away with spraying only one or two years, but without it, more may be needed. Overall, he believed that the future approach is to be a more integrated one, and that if one decided to go the route of silviculture alone for controlling the budworm, he/she has to be ready to sustain some losses.

This discourse on limitations and advantages of the SBDSS has some similarity to the discussion of Holling's model above. It is useful to give a comparison here because problems that were made apparent in Holling's model may still be quite applicable to the present case. In both cases, ecological data are compiled and future effects on the forest are extrapolated. Also in both cases, the data only indicate what the effects of outbreaks will *likely* be, but it is up to the decision-maker to decide what to do with it. Both are designed as an *aid* to decision-making by offering scenarios for what the results of different management choices might be (to spray or not to spray for example). The SBDSS certainly has added precision over Holling's model due to the greater resolution of more sensitive and thorough technology. The limitations in either case need to be taken seriously though. As described by Holling (1978, p. 170), "…what is left out at each stage of the analysis is much more important than what is kept in." Through the limitations and assumptions, what is considered important is defined. This will be discussed further in the concluding statements.

Environmentalist Pressure and the Adoption of Bt

The crucial points of the proposed system have just been described, but it is also important to address the sociopolitical environment that has pervaded the forestry community during the period since large-scale spraying ended. This will give some idea of how the SBDSS fits with larger societal trends related to the forest. Despite the desire for increasing industrial productivity, the proposed program has been advocated as more environmentally benign and sustainable than the past program (Carrow 1995). The global environmental concerns brought to light through the Bruntland Commission (1987)—with the Rio Summit following—and the research and development recommendations in Canada for more clean technologies were stated as indicators that future changes were coming about in insect control programs *vis a vis* the environment (Carrow 1995). An apparently greater consideration of public participation was also included as a future goal.

The prohibition of fenitrothion in 1998, and the focus on the more environmentally benign Bt as the current budworm control tool may be an indicator of a necessary shift in the industry towards methods that generate far less negative publicity than those used in the past. It should be noted that the relatively recent prohibition of fenitrothion has changed the outlook of forest protection drastically. As recently as 1995, the statement was made that "The need for chemical insecticides will remain, but dependence on the biological insecticide Bt will increase" (Sanders 1995). Baskerville (1996) alluded to this concern in the industry when he explained, skeptically, that (p58): "…some believe that it is worth using a publicly acceptable, if expensive and less effective, material if it reduces pressure from the environmental lobby."

As described previously, the spray program in the past was affected somewhat by regulated prohibitions on spraying within one mile of habitations and within 3.2km of blueberry producers' fields, which were the result of publicized complaints and court battles. The industry is apparently ready to implement a spray program based entirely on Bt for the present, with which the restrictions are much less. Instead of a mile buffer zone from habitations, it has been set at 155m; a 3.2 km buffer zone remains for blueberry fields, but only for large spray planes, while there are no restrictions for small planes; no limits are set for designated rivers and open bodies of water; but, a 3.2 km buffer zone remains for municipal water supplies (Carrow 1995).

Bt is the insecticide the SBDSS simulations are currently based on. It is important to address this link. The SBDSS is supposed to be a tool for increasing the efficiency of forest management over the long-term by increasing the ability to predict long-term timber outputs. Bt's effectiveness needs to be very predictable at a quantitative level as a result. According to the very recent "Cooke Model" for Bt efficacy, there were several gaps in knowledge of effectiveness of Bt (Regniere and Cooke 1999). These included a lack of understanding of budworm development and feeding rates on red spruce, black spruce and heavily defoliated balsam fir. There were also some concerns over determining the quantitative effect of budworm defoliation on heavily flowering balsam fir. These claims certainly suggest some difficulty in moving beyond a very simplified look at forests. The limits of the Cooke Model were hinted upon with the statement (Rengiere and Cooke 1999, p.15), "…perhaps the most pressing need is to address scientific issues related to the use of the model on host plant types other than healthy, mature balsam fir."

Effective functioning of the new program will require more specific timing in spraying and greater dependence on cooperative weather than in the past because of the proposed use of Bt (at least in the short-term), which can only be effective if used at comparatively more specific times and under more specific weather conditions than past chemicals (Cunningham and Frankenhuyzen 1991). Bt has been demonstrated as being effective in the declining phase of outbreaks, but there is some anticipation over whether or not it is *sufficiently* effective throughout the outbreak. Even though work has continually been done to test more concentrated and newer strains of Bt, Baskerville recently described the agent as more burdensome than its predecessor control agents. In his very critical evaluation, he viewed that industry would have to reexamine its sustainable harvest level if Bt became the weapon of choice (Baskerville 1996).

Despite the fact that it has produced much less concern than the previously used insecticides in New Brunswick, there has been significant concern developing. Although the insecticide has been touted as a safe alternative to the chemical insecticides used in the past, it does have some known risks. One strain, *Bti*, was used for mosquito control in the Florida Keys, but the control program also had the result of killing non-target insects from the same family as the spruce budworm (Lepidoptera), including the endangered Schaus swallowtail butterfly (Scriber 2001). Although the problem was potentially caused by contamination of the *Bti* spray formulation by microbial contact, the problem was still a legitimate one. Non-target Lepidoptera killing has also been a problem with *Btk*[vi] sprays and this has generated a lot of negative public reaction across the United States, where Btk has been used extensively for gypsy moth control (Scriber 2001)). Bt has been prohibited in at least one case in Canada. In 1998, a program to control the European gypsy moth in Victoria B.C. using Bt was cancelled due to public pressure (Smith 1998), but this may have largely had to do with the location of the spray target in an urban area (MacLean 2002, pers. comm.).

Since Bt is regarded as the only chemical expected to be used for the following program, the environmental concerns are expected to be minor. David MacLean's assessment was that Bt will cause less concern due to a smaller amount of active ingredient, the fact that it requires ingestion to take effect (not simply contact), and because the public was apparently happy with the proposed system at recent provincial discussions with stakeholder groups (MacLean 2002, pers. comm.).

In the case of Bt, human health effects have not been shown and it is not currently perceived as any threat; however, human health problems were only part of the controversy of the past spray program in New Brunswick. The case of Bridges Brothers versus Forest Protection Limited clearly indicated that killing of non-target insects could negatively affect the livelihood of non-timber forest products producers, and that the effect was socially and financially unacceptable since regulation ensued. Obviously, it would be unrealistic to assume there would be absolutely no negative public reaction to Bt use in New Brunswick if the killing of non-target insects results—still a problem with Bt; there is also the precedent set by the case in Victoria to think about. It seems then that unless some significant advances are made in the next few years with regards to the non-target effects, there may be the potential for another public outcry.

The perception of Bt has certainly been mixed though, as a present case suggests. Present plans for spraying Bt on gypsy moths in one area of New Brunswick, due to concerns by cottage owners over the effect of a gypsy moth infestation on the aesthetics (including smell) of the area, presents a contrast to the case in Victoria (MacLaughlin 2002). The belief of these cottage owners was that Bt did not pose any significant health or environmental hazards, leading to the conclusion that it was safe for use in areas that they would be present in. The short and long-term effect on the aesthetics of the area—those that the cottage owners have become accustomed to—were considered to be more detrimental than any effects that Bt could produce. Since this is only one case, it would not be accurate to say that it represents the views of the entire province.

A Diversity of Tactics for Future Budworm Management

Along with Bt, many other agents are being considered, but for the long-term rather than immediately. In the long-term, three stated goals for success of budworm management are (1) proactive management of indigenous and exotic pests, (2) minimization of pest epidemics by dealing with endemic pest levels, and (3) development of new tools on a continual basis. It is expected that over the years, the style of management will shift from the use of one method/one spray to an integrated management approach. The public perception of insecticides in the past was viewed as a concern and clearly something that needed to be weighed in the future (Kettela 1997).

As part of the long-term strategy, biological control agents are being developed for commercial use; they are expected to play a major role in the future, but they are currently considered far from ready (Kettela 1997). The proposed tools include natural enemies, semiochemicals (for example pheromones or other chemicals produced naturally by the budworm[vii]), microbial control agents, natural products (such as NEEM[viii]), and viruses. In all cases, the time horizon until usability is 5 years or greater. The reasons for delays are twofold. In the case of viruses, registration is an arduous and long process because recombinant viruses are regarded as potentially dangerous. The other methods/chemicals were considered either not entirely safe or not effective/predictable enough, needing further development. In general, the tools are very similar (if not the same) as the agents that were described over twenty years earlier when the prospects for biological control agents were brought up (Miller and Varty 1975, see previous chapter). In the intervening years, they have not been implemented commercially, except for very minor cases with semiochemicals. This certainly puts some skepticism on these tools being taken seriously at present.

There has been no mention yet of the use of these alternative control measures within the framework of the decision support system. This raises another point. The SBDSS was designed with aerial insecticide spraying in mind, where the ecological interactions between spraying and the forest are understood based on (mostly) the last 50 years of data, but biological control agents (other than Bt) are not so well understood. Recall that in Holling's model (1978), biological control agents were left out of the primary part of the analysis for the purposes of simplicity. The fact that there is very little data on the effects of biological control agents on budworm certainly makes it difficult to see how they can be important in the short term with the SBDSS.

Increasing Control of the Forest, Reducing the Unpredictable

A little less on the speculative level, it has been made clear that even-aged management of the forests of New Brunswick is still desired. Despite the fact that the link between even-aged management (through clearcutting) and ideal budworm conditions (continuous areas of mature balsam fir) has been acknowledged (Blais 1983), the method has been justified as the only way to manage the fir-spruce forests of the province. The clearcutting method has been described as the soundest approach to manage spruce-fir stands (Baskerville 1983, p.7): "…where even aged stands presently exist, clearcutting is the most appropriate way to manage spruce and fir." This spruce-fir forest type has been described as occurring naturally in even-aged stands (Baskerville 1995). This "natural" way of managing such stands has tended to lead to the regeneration of even- aged balsam fir, and this brings more budworm (Blais 1983).

Obviously, the consequence of this unfortunate side effect for the industry has been a need for more active control in order to maintain or increase the timber supply. The *potential* losses due to any natural or unnatural causes—fire, diseases, insects, harvesting, etc—need to be kept under control for the timber supply to remain steady or increase, which requires maximum predictability of these disturbances. The shift that has occurred towards increasing numbers of and/or sizes of plantations containing controlled species compositions and selected genetic varieties therefore makes sense. This shift is expected to continue as more controlled forest management is expected to arise in the future (Conservation Council of New Brunswick 2001). In a statement about the trend in forestry in Canada, Carrow (1995) described (p. 723, my emphasis),

> As we move towards *more intensive management* of the new forest, insect control to preserve annual growth will become more common. Indeed, as we exhaust the supply of old-growth natural forests, it will become more important to ensure that our *new forests* are developing as *predicted* in provincial timber supply projections.

The supply projections are obviously precarious enough that there is some concern about whether or not they can be met without more stringent active control of mortality factors.

The earliest of the planted forests, as described by Baskerville (1983) will be reaching harvestable age (approximately 50 years old) between 2020 and 2030. It is obvious that the SBDSS will function more optimally if predictability of the forest and budworm are maximized. It is also a fact that diverse forests are difficult to model, and in the case of New Brunswick, this difficulty leads to more complications with budworm management. In this context, the usefulness of plantations is clear (O'Hara 2001, p.82, my emphasis):

> A basic premise of plantation management is that uniformity creates efficiency. This *efficiency* is translated into stand management *efficiency* in planting, pruning, thinning, harvesting manufacturing, and in predictability of management activities and the results of management activities.

As described above (Erdle 1989), greater industrial *efficiency* is the main utility of the SBDSS. Although a "need" for greater efficiency does not necessarily lead to plantation establishment and greater control over a forest's ecological cycles and events in general, it does put pressure to head in this direction. Efficiency (economic) could also be sought at the manufacturing stage and through finding more uses for what is naturally available in the forest. Impinging on biodiversity, structural diversity, and genetic diversity is therefore *one* means of furthering industrial/economic efficiency in wood fibre production. The problem of (re)introducing such diversity (after it has already been denuded), from the point of view of industrial efficiency, has been described as:

> …an issue of changing from a structure that is very simple, homogeneous, and relatively well understood to one which is highly variable and with many complex interactions (…) variability could come in the form of spatial patterns, species, genetic diversity, density, and tree age(O'Hara 2001, p.82).

This point on biodiversity brings up an important obstacle to the introduction of silviculture as a budworm management tool. This same problem was brought up in the previous chapter. Silvicultural manipulation, with the idea that certain compositions and overall biodiversity increase budworm resistance, will necessarily lead to some unpredictability because there is some forsaking of control[ix]. It seems to be a choice between accepting *some* unpredictability and *some* losses to the cash crop or else instituting maximum control and accepting damage to non-target species.

Plantations are considered to be on the decline right now with regards to amount of planting. This is largely due to budgetary reasons, although J.D. Irving Ltd. has maintained their level (MacLean 2002, pers. comm.). Precommercial thinning has increased while planting operations were decreasing over the late 1980s and 1990s. This method is only useful, however, for reducing budworm damage if the stands are not pure fir. MacLean mentioned that work is being done on precommercial thinning, where it has been found that stands can handle defoliation for a few years, and will return to a healthy state if spraying were done as a last resort. Obviously, some growth reduction would be accepted in this case, but less spray would be used overall, perhaps making it more cost effective in the long run; it is an example of a more integrated approach. MacLean's view was that plantations have not been targeted very well in the past in terms of appropriateness to the landscape and compositionally, therefore their potential was not maximized.

The New Spray Program's Response to Past Criticisms

A summary of the prior discussion in this chapter will precede the main discussion in this section. The main points up to the present in this chapter are as follows:

1) Computer modeling enters into the picture in the 1970s, and was seen as a tool that would provide hope in solving the spatial and temporal softwood management problem in which the budworm was a crucial factor.
2) The SBDSS comes into being during the 1990s as the next step in budworm management, with the claim that protection would become more efficient.
3) Aerial spraying of insecticides is still considered a necessity, and the proposed approach is heavily reliant upon it, but other methods of control are also identified for possible use in the future within the framework of the system.
4) Bt enters in as the new “safe” weapon of choice, but there are issues with its efficacy and also some arising environmental concerns, but in general they are greatly reduced relative to the past program.
5) Other control agents are actively developed for use in budworm control programs in the future, but their place cannot easily be rationalized in the model in the short-term because their interactions with the forest environment (including the budworm) have not been tested.
6) Predictability was defined as a potential problem—at least with respect to Bt use—but a requirement for effective management. As well, more pressure is expected on the fibre supply in the future. The increasing reliance on plantations seems a forgone conclusion.

With the background of the proposed system in place, a comparison between it and the past approach can commence by using the past criticisms as a medium. The main criticisms of both the past program and of the forest management that preceded it—and pervaded it—will be used to judge the proposed program. The justification behind this approach is that these criticisms continued to appear in the literature through the past, so if they have not been addressed in the proposal for the future control approach, they are unlikely to simply go away. The following section is the culmination of the historical analysis, where the criticisms identified in the summary of chapter two will be used to assess to what extent the proposed program is a response to the past criticisms.

1) Human influence, largely protection spraying and clearcutting, created the problem of massive and severe budworm outbreaks, so they need to be curtailed.

Briefly summarizing this debate, the criticism that human influence created the budworm “problem” is a criticism of historical forestry practices during the colonial period and practices that developed through to the period when the pulp and paper industry became dominant.

During colonial times, the problem was highgrading (Baskerville 1983, Tothill 1922). It began with highgrading of white pine and was followed by the same for red spruce through the early years of confederation into the 20th century. The same was the fate of other more valuable species until the pulp and paper industry entered into the picture to create marketability for the remaining trees. This form of selective cutting has been regarded as a negative human influence (Tothill 1922, Baskerville 1983). Insecticide spraying, fire prevention, and clearcutting have been more recent concerns (occurring over the last fifty years). These last three have not been curtailed, but increased until the 1980s (Blais 1983)[x]. Through the history of active budworm management, these criticisms never led to any changes because they were not in accord with the economic policy of the industry: continual expansion.

Will the effect of these human practices be reduced through the proposed system? From what has been discussed above, it is obvious that the proposed system is designed to be an aid for increased industrial efficiency. The industry has felt a real danger over what the future (next thirty years) will bring with regards to wood supply (Baskerville 1983 and 1995, Carrow 1995). The increased efficiency promised through the new system is therefore promising from their standpoint.

The *effect* of insecticide spraying as a control method is important to bring up here because whether it is Bt or DDT or any other insecticide, trees are still kept alive, though chemically dependent on further human inputs for survival. The budworm is prevented from killing its own food supply and, it has also been argued, the spray kills natural control factors as well (Restino 1993). In the context of a criticism of human influence, therefore, the argument is against *any* external control method that keeps trees alive, preventing what the entomologist Samuel Graham described as natural compensation (Graham 1956). Does the new approach include provisions to allow more natural compensation? The answer is yes, theoretically. It would fit under the option of "do nothing and accept the consequences", which is regarded as legitimate under the new approach, but such an option would be undertaken only if the desired harvest volume is not compromised or if costs are prohibitively too high to allow full protection spraying or other control methods. These areas would be where the least valuable stands are or where stands are expected to be particularly resistant to defoliation impacts. Such areas would not likely be significant in size.

Probably the most visible human impact on the forest, clearcutting, has been criticized as a major factor leading to large areas of budworm susceptible forest (even-aged and mature balsam fir), but this effect has been diminished somewhat by planting operations. Although plantings have become more prominent since the 1970s[xi] (NB Dept. of Nat. Res. and En. 2001), diminishing to some degree the importance of balsam fir, a large number of fir are still expected to be a part of the prospective harvest until around the 2030s. Survey data from 1979 (Dept. of Nat Res. 1981) shows an overall greater portion of spruce than fir (approximately 5.9 billion cubic feet versus 4.5 billion cubic feet), but amongst the youngest trees there was more fir than spruce (approximately 1.15 billion versus .95 billion cubic feet), which means more forest protection concerns for the future. The amount that ecologically abnormal quantities of balsam fir regeneration are prevented depends on how extensive the planting programs have offset the fir quantity. As described by MacLean (2002, pers. comm.), industrial harvesting and fire protection practices created conditions that encouraged fir regeneration.

The SBDSS, since it is designed as an aid for long-term forest management planning *may* call for less clearcutting in order to ensure that the wood supply does not slowly dwindle, or may call for less clearcutting due to a lesser amount of fibre through defoliation. The amount of spraying *is* expected to be reduced through better targeting of susceptible stands. The key is that the system is designed as an industrial aid. It is not designed to find the best areas to protect or to simulate ideal selective cutting programs for the betterment of overall forest biodiversity. A reduction of human impact may be an indirect effect of increased industrial efficiency. In the end, selective cutting (minus the highgrading), which is more congruent with the goal of reducing human impact, likely will play no more than a small role in the proposed management scheme—wherever silvicultural manipulation is designated. In considering how harvesting can be done to cooperate ecologically with the budworm outbreak cycle, J.D. Irving Ltd. is supporting a project to see what happens if they only harvest what would be taken by the budworm, leaving small islands or clumps. It is left to be seen what becomes of this project.

2) The biodiversity of a forest strengthens its ability to resist damage from budworm, thus biodiversity needs to be actively restored rather than diminished.

The criticism over human influence leads directly to a more specific criticism: that human influence has caused an overall loss of biodiversity in the forest, which has weakened its ability for self-management. Through this more specific criticism, suggestions have been made to restore the "lost" biodiversity in order to re-invigorate the forest's "natural" insect control capacity (Tothill 1922). In the past, this biodiversity loss (Zelazny and Veen 1997) has never been taken seriously by the industry as a real threat, or has been completely incongruent with industry's economic demands, or both.

The idea that forests could be made resistant to budworm outbreaks, an idea brought up by Tothill (1922) and reiterated by Hawboldt in the 1970s (in Sandberg and Clancy 2000), had to do with the idea that an increase in structural diversity and biodiversity leads to greater parasitism and predation of the budworm, and to an overall reduction in food supply. On the notion of whether or not forests could be made budworm-proof, MacLean (2002, pers. comm.) described that since the budworm has been around for such a long time (evolutionary relationship with the forest), periodic outbreaks of some level can be expected regardless of silvicultural measures, perhaps with minor exceptions in unique areas of New Brunswick. Northwestern N.B. and the border between N.B. and Quebec were described as places of regular outbreaks. The Cape Breton Plateau in Nova Scotia was also mentioned. According to MacLean, budworm will always find its food, even in mixed and young stands.

The character of what was meant by the argument for biodiversity, with respect to budworm control, has been developed since the 1920s when Tothill described the role of predators and parasites in ending outbreaks; these old arguments have not lost relevance in the present. Charlie Restino (1993) commented how fenitrothion killed massive quantities of warblers, which are a predator of the budworm. Mortality of birds is the reason that fenitrothion was actually prohibited in 1998. Even more recently, Needham et al (1999) described how hardwoods mixed in with balsam fir led to less defoliation of fir, and the reason given was that the complexes of parasites and predators was surely strengthened. The exact complexes involved could not be identified.

In order for the proposed strategy to be a potential success at providing the basis for some restoration of lost biodiversity—in the context of dealing with the budworm problem—there has to be a clear inclusion of the value of biodiversity embedded, at some level, into the SBDSS. In other words, the system would have to include the complex of factors that together bring about the natural conclusion of outbreaks. Without such an inclusion, biodiversity will continue to be marginalized and the criticisms will likely not go away. Of course, the inclusion of such complex factors takes away the transferability of the model, a problem pointed out by Holling decades earlier. Currently, there is no indication that biodiversity is included as a variable in the system.

Further in the future however, a transition may occur. MacLean (2002, pers. comm.) expressed that an integrated approach is the focus for the future, an idea affirmed by others (Kettela 1997, Carrow 1995). A more integrated approach encompasses the need for maintaining or restoring biodiversity. Integrated Pest Management (IPM) has been defined as (Simmons et al 1984, p.12):

> An ecologically based pest control strategy that relies heavily on natural mortality factors such as natural enemies and weather and seeks out control tactics that disrupt these factors as little as possible. IPM uses pesticides, but only after systematic monitoring of pest populations and natural control factors indicates a need. Ideally, an integrated pest management program considers all available pest control actions, including no control action, and evaluates the potential interaction among various control tactics, cultural practices, weather, other pests, and the crop to be protected.

This is an idealistic definition of IPM, and in any specific case there will be more specific definitions. In the case of New Brunswick, since IPM has not been implemented, a specific definition does not yet exist.

In terms of the SBDSS actually being used as an aid for assessing biodiversity, Deer Wintering Areas (DWA) and Mature Coniferous Forest Habitat (MCFH) have been mentioned for consideration within the analytical powers of the SBDSS. Some tests have already been done on this potential (MacLean et al 2001), but the capability of the system is limited by its evaluation being based on representations of species as wood volume. MacLean mentioned that looking at the forest in terms of volume alone is only one measure, and that there were other factors that needed to be considered, such as snags (2002, pers. comm.). This is at least one example of an attempt to integrate the importance of biodiversity into the system, but with obvious limitations.

If the proposed use of Bt is considered a part of the proposed approach, then biodiversity is certainly assisted as a result. The adoption of this agent was the result of regulatory pressure and the industry being concerned about public opinion in general. This has been in spite of the fact that Bt has been regarded as less effective than other agents. Although there are still non-target effects that result from Bt use, they are (as far as can be told until now) much diminished compared with other agents used in the past. This is despite the fact that the strength of Bt (as a budworm control agent) has increased over the years to approximate the strength of past control agents (Carrow 1983, Cunningham and Frankenhuyzen 1991). The value of biodiversity has therefore made its way into the management approach at some level as a result of the adoption of Bt. It is however only implicitly, not explicitly.

Overall, the measures within the proposed approach may help biodiversity maintenance, to some degree, but there is no sign that restoration of what was diminished in the past has been included. As well, limitations on harvesting and overall forest control measures have not been considered explicitly, with the exception of various buffer zones for bodies of water, habitations and other designated areas.

3) Time is required to restore the forest's strength, thus forest management should be focused on making long-term silvicultural and biological investments.

The relatively lengthy time required to restore a forest's composition, to implement mixed species stands, and to (re)-institute natural enemies of the budworm (and exotics) has been a deterrent to adoption of silvicultural and biological controls. Baskerville brought up this point in the context of skepticism of silvicultural budworm control. This may be one of the main reasons that silvicultural control has not been used even on a small-scale level. He argued that changes in stand composition to reduce susceptibility would take 100s of years, (Baskerville 1975b), which was in contrast to what was said by Tothill in 1922. Tothill described that 30 years was enough to see a change. Hawboldt (in Sandberg and Clancy 2000) also argued that if Tothill's warnings about a future budworm outbreak had been heeded, and changes had been made to restore more "natural" species compositions, spruce budworm outbreaks would not have become nearly so severe. His view was that if early silvicultural recommendations would have been followed, forests could have been budworm-proofed by the 1970s. Pickett, in describing management of fruit orchards, also stressed how the long-term needed to be kept in mind. In reference to natural enemies of troublesome insects, he made it clear that those natural enemies driven away would not come back instantly (Creighton 1963, p.72): "You can't just shift over night and then expect miracles. These animals you have been killing off for twenty-five years are not sitting on a rail fence waiting to come back."

As already emphasized, the proposed system *does* involve a long-term focus, but from the perspective of the industry. It is designed to give a greater assurance that adequate timber volumes are available over the long-term, but only of the marketable species. The system has been formulated to deal with a problem that was identified in the past: the disparity between volumes of timber "lost" to the budworm and harvesting and the volume added through new growth, all over long time frames. There is no indication of measures to include long-term survival of the forest community as a whole along with the industrial demands. The problem with including the long-term survival of the forest community as a whole into the system is that it introduces great (perhaps unmanageable) complexity into forest management planning when management involves great spatial and temporal scales.

Respect of the long time period required for implementation of silvicultural and biological control measure can only be granted insofar as these measures are included into the proposed strategy. As has already been described, these measures do have a place in the strategy, silvicultural measures in selected areas and biological measures as a future goal, but the

SBDSS is primarily focused on ensuring that wood volume is managed most efficiently on an annual basis in order for a sustainable supply to remain. Clearly there is a conflict here. Respecting the time period required for nature to take its course would mean some sacrifices in the present, and this is not a goal for management in the near term.

4) Spraying causes a need for more of the same, thus it is an ineffective and unsustainable measure in the long-term.

The only reason that insecticide spraying came about at all as a management technique is that the industry in New Brunswick was pushing ahead for continual expansion and required an immediate solution to the imminent threat to their hypothetical timber supply. This pressure necessitated a method that would allow the opening up of additional resources for the availability of the industry. Spraying of insecticides was this method. Despite the intensive and extensive use of insecticides, the budworm would keep coming back in high numbers, the only benefit being that *prevention* of tree mortality was actually achieved (Blais 1974, Baskerville 1978, Blais 1983). The Concerned Parents Group went further, advocating the position that budworm which survive insecticide spraying were hardier: flying further and laying more eggs—capitalizing on the loss of the weaker competition (in Swift 1983). Although spraying allowed the "saving" of trees that may have otherwise died by way of the budworm, the industry seems to have been overzealous in exploiting this surplus. Currently, there is an expectation that there will be a timber supply shortage by around 2020 in New Brunswick (Baskerville 1983).

The fact that insecticide spraying, to some degree, represents an entire ecological cycle played by humans—replacing the natural one—has been acknowledged to some extent (Blais 1974, Baskerville 1978). The question must arise of whether or not humans are prepared to take on this role without faltering. If they are not, then the resource that has been built up largely through human activity will begin to decline. Baskerville (1995) heavily criticized the supposedly insufficient coordination of spraying and harvesting operations of the past for the decline of the future resource. At the same time, he praised the prospects offered through simulation models.

It seems that the SBDSS, in theory, is prepared to deal with this coordination problem. The SBDSS also enters into the picture to deal with the over zealousness mentioned just above. In this sense, the proposed approach may actually make insecticide spraying more sustainable, at least from an industrial perspective. Yearly spraying would still be required, however, because the demands for timber still require the surplus created by spraying. As described by MacLean (2002, pers. comm.), the SBDSS will result in an improved targeting of spraying, so the overall effect on the forest of continual suppression of budworm populations would be reduced to some degree. If the effect of insecticides on making budworm hardier is considered—something that seems to have eluded exploration—then the level of insecticide used becomes more of an issue. Overall though, it appears that the SBDSS will offer some relief of insecticide use and it is quite clear that the problem of over-spraying on a yearly basis was considered during the design of the approach.

5) Chemical insecticides are too dangerous to faunal and human health to be justified.

Although the use of Bt has already been mentioned in relation to biodiversity above, it will be addressed in more detail here. When the utility of Bt was first being considered in the 1960s, its marginal effect of only slowing down the feeding of budworm was not significant enough to warrant its use as a forest management tool. The industry required a thorough killing of budworm, represented by a 60% reduction in defoliation of balsam fir and a 50% reduction for red and black spruce, which was provided by DDT at the time.

Bt is now considered the primary tool for budworm control in New Brunswick, but over the last thirty-something years its effectiveness for killing budworm has been engineered to approximate the toxicity of past chemicals (Baskerville 1995, Carrow 1995). These past chemicals, as described in chapter one, were all regarded as dangerous at some point, and all were eventually prohibited. Can Bt escape this fate? It is professed to be a “new age” insecticide in that it is a lot more environmentally benign than the agents used in the past; however, it is not without problems. Some of these have already been described. The use of Bt with the SBDSS certainly may keep the image of the SBDSS cleaner than the program of the past, but the adoption of this agent as the main option was not motivated by the creation of the SBDSS. It was an entirely separate issue, an overall environmental concern.

History has shown that the use of any insecticide that has an “acceptable” level of effectiveness will entail the sacrifice of at least some other forest fauna. This is still apparent, albeit greatly diminished, in the proposed strategy. The justification of the sacrifice to other forest fauna continues, but it is somewhat abated. The danger of Bt to other lepidopteron insects is an issue that is not explicitly addressed in the SBDSS framework. It is therefore quite likely that the issue will come up in future debates, possibly in the same confrontational context as the past debates over insecticide toxicity. Overall though, some compromise has been made with the adoption of Bt because it is considered the best current option despite the fact that it is not regarded to be as effective as the other agents. A balance between efficacy and environmental safety has therefore been established. This compromise certainly makes it apparent that the use of Bt represents some limitation on what can be sacrificed.

Much of the debate over insecticides presenting too much of a risk stemmed from concerns over human health. Although no link between Bt spraying and human health has yet been demonstrated, enough public resistance can still be generated through other concerns to halt its use. The example of Bt being prohibited from use for gypsy moth control in Victoria and the stoppage of fenitrothion use in New Brunswick because of loss of bird life makes it clear that destruction of forest fauna is enough to halt a spray program. Since the SBDSS is insecticide-intensive and the past discontent over spraying was never resolved (through a change in the approach or public acceptance), it is fair to say that the debate over the justification of insecticides (biological or chemical) is still lingering.

Conclusion

Although there has been much criticism of the development of the forestry industry over the 20th century, as well as even more criticism through the course of the spray program, there has been no large-scale shift in management in New Brunswick. Minor concessions have been made, representing mainly curtailments of past management, with little response to concerns on a complete level. Of course, re-consideration at this level would require a serious societal demand for such change. One can simply turn eastwards to Nova Scotia to see an example of actual resistance to the dominant industrial management paradigm (Sandberg and Clancy, in press). This was in spite of the fact that the "need" for spraying was heavily vouched for. Eric Sunbladt, president of one of the largest forest companies in Nova Scotia, Stora Kopparberg, made the historic statement that: "Nova Scotia is sick and must take its medicine" (Restino 1993, p.32). In Nova Scotia, the prevention of spraying was an example of societal values taking precedence over industrial economic values. Only one spray was used on a small scale, and that was Bt (Restino 1993).

So what can be judged of the new program? Will it offer some improvement over the past program from an environmental standpoint? The present analysis shows that the system is indeed an attempt at long-term resource management, but within the conditions prescribed by the industry. The proposed approach arose out of a need to remedy what Baskerville (1995) described as the forest management problem: that harvesting and protection were not coordinated well enough spatially and temporally, leading to long-term supply problems. In this sense, it is an improvement over the past program, but perhaps only from the perspective of the industry. It is debatable if the general views of successful forest management defined by the proposed management approach conform to the views of the people of New Brunswick.

Hypothetically, the overall outlook of the next phase of budworm management seems to be much better environmentally, mostly due to the softer nature of the insecticide Bt. Although there are threats to non-target species, some face has been saved by the fact that no human health problems have been shown to be linked to Bt use in the United States, where it has been used much more heavily. Up to the present, there has been no concern over the same in New Brunswick either, considering that Bt has been used periodically through the past. Still however, in New Brunswick where there are high expectations for the protection program, and where extensiveness of insecticide spraying on forests would rival any other program on earth, problems may arise with regards to overuse if care is not taken. The non-target mortality of other lepidopteron insects has to be dealt with as well. As mentioned in the previous chapter, controversy arose in the United States over this problem when gypsy moths were sprayed, and a Bt spray program for gypsy moth control in Victoria, B.C. was cancelled, so it should be expected that the same *could* occur in New Brunswick. Kettela (1997) actually alluded to public concerns as being an important factor to consider in the future of budworm management, clearly indicating that some problems may arise.

It seems that with the present demands by industry for greater allowable cut levels in New Brunswick (Conservation Council of New Brunswick 2001), wood loss will be more unacceptable. With such great economic pressure on the forests, with much of the volume being allocated to pulp and paper production, and with forests being grown to fit the specific demands of the industry, it is difficult to imagine how the classical biodiversity-focused ideas of forest management can be implemented. Herbicides are used extensively to limit the growth of undesirable hardwoods (Department of Natural Resources and Energy 2001), protected areas are advocated against by large industry as taking away jobs. It may be that the only way that any scientific or other criticisms can have an effect on the solidified economic power structure of the forest products industry in New Brunswick may be for a revolution to take place in the industry where multiple products are produced and communities are made responsible for management decisions. If such decisions are rooted in a local understanding of the forest, be it scientific or otherwise, there is far less likely to be the kind of province-wide backlash by the public over management decisions.

The trend in the forest products industry through the past has been towards production of mostly pulp and paper, which has likely constrained the development of other industries due to the lack of production and manufacturing facilities for other products. As described by Karen Lie (1980), the industry in New Brunswick was able to increase from an annual harvest of 1,404,000 cubic metres to 2,500,000 cubic metres from 1952 to 1976, which was a consequence of the mortality prevented by spraying of insecticides—although the influence of more advanced harvesting machinery that allowed more extensive harvesting should not be discounted.

Baskerville also praised the role the spray program has played in the growth of the industry. As described by Blais (1974) and Baskerville (1978), if the pattern of nature was allowed to unveil itself (as it has been covered by spray for the past 50 years), then the budworm would play its role in reducing the quantity of balsam fir and allowing the regeneration of the next stage of forest. S.A. Graham (1956) offered the notion that the spruce budworm is acting out the law of natural compensations, such that when the mature balsam fir population reaches high levels, the budworm enters into the picture to compensate. The reason that the budworm has not been permitted to play its role is that industry could not afford to lose the excess volume generated through spraying; growth of the industry was contingent on as little foliage as possible being lost to the budworm.

The proposed strategy, with the SBDSS being the main component, does not address the importance of ecological relationships in forest dynamics. The analysis in this paper has shown that the sustainability of the level of harvesting was scarcely questioned in the sphere of industry or government through any part of the past program or the proposed one, perhaps the main exception being the comments of Blais. Blais admitted that practices (including spraying and clearcutting) have been destructive, but then diminished his comment by explaining how the economic need for harvesting outweighed these problems (Blais 1974).

Perhaps the spray program would never have been considered cost-effective if it were not for the funding given through both the provincial and federal government. Due to the provincial government ownership of Forest Protection Limited, there was a natural inclination for the province to cover much of the spray bill. The federal government also provided some funding, but the intense controversy that led to the prohibition of DDT enticed a federal pullout from further financial assistance to the spray program. The industry had also just started to use the more expensive fenitrothion and the greater costs of fenitrothion plus the lack of federal support constrained the provincial budget. The provincial natural resources minister Roland Boudreau reacted by announcing a potential return to the cheaper but more dangerous DDT in order to save costs. Federal funding then returned (in Karen Lie 1980). Obviously, without the provincial and federal contribution, the spray program could not have been conducted so extensively. The cost-effectiveness of spraying (at the level it had reached) would have been reduced significantly if private industry had to provide all financial resources themselves.

Perhaps the most recurring theme identified in the spruce budworm debate has been the refutation of silvicultural and biological control methods as incomplete and unquantified. A particular constraint that is important in addressing why these methods could be continually dismissed has to do with the nature of ecological research in general. In a controversial article by Ludwig et al. (1993), the idea of basing natural resource management on ecological research was criticized. In support of their claim, they brought up heterogeneity in ecosystems as well as the impracticality of running controlled and replicated experiments when the spatial and temporal scales are so large. The result of this problem was concluded to be uncertainty, putting ecologists in a precarious position when trying to give politicians consensus recommendations for sustainable management of natural resources. Their conclusion was that the limits of natural resistance to exploitation could only be discovered by bringing systems to a point of collapse. This gives pretext for unrestrained exploitation and the use of any control measure until such a point is found. It also diminishes the hope of increasing the efficacy of silvicultural and biological control measures. Of course, the conclusion is based on the idea that uncertainty is unacceptable, which is highly debatable.

There is some suspicion that the industry in New Brunswick is headed down a path where plantations will be more commonplace. The larger industrial members in the province have called for a doubling of the allowable cut by 2050, a move the Conservation Council of New Brunswick charges can only occur if plantations cover the province. The present levels of harvesting, an annual allowable cut of 3.5 million cubic metres, have been called unsustainable by the Council under the rationale that forest biodiversity has been on the decrease. Their suggestion therefore is for curtailing rather than increasing current harvest levels (Conservation Council of New Brunswick 2001).

Through the criticisms by the Conservation Council, an evidently missing consideration becomes apparent in the vision of industry and the provincial government for forest management in the future: biodiversity. Biodiversity provisions were not considered to be an important component in the Decision Support Framework. Re-addressing a previous point becomes important to illustrate this dearth. What about the classical concerns for biodiversity and the forest's inherent ability to regulate itself? These have been largely ignored, part of the reason being potential overcomplication (considering the economic goals). Points on biodiversity have been brought up recently though, one instance being research which showed that hardwood content, with its added biodiversity, helped to buffer fir-spruce stands from budworm devastation (Needham et al 1999). Canadian Forest Service scientist Judy Loo (1997) also put scientific basis behind the indispensable role of biodiversity in a forest's regulatory processes when she reviewed the link between biodiversity and forest function using examples from other regions of the world.

An interesting phenomenon that may have occurred over the last century is a possible chemical dependency. If the entire forest is being sprayed for the budworm with only pockets of non-sprayed area representing a minority, then these pockets might receive flocks of moths trying to escape the sprayed areas. Perhaps this is a problem, but one can only speculate due to the lack of information. Baskerville did mention a problem in the past of chasing the budworm around the forest (Baskerville 1995). According to one source, small woodlot owners felt the bite of budworm outbreaks as well. Forest landowner Lawrence McCrea explained that he had little choice but to switch from selective cutting with horses to clearcutting with skidders. He also began to spray, but only intermittently; he believed that spraying was not a substitute for forest management; however, he also made the point that had he sprayed every year, the prevented mortality would have allowed him to continue selective logging (MacRae 1979).

The story of McCrea switching to clearcutting and intermittent spraying after years of selective logging illustrates a possible problem with classical approaches. When so much of the forest has changed in response to human influence, the impact of certain management activities changes as well. Holling described in his study (1978) that the industry had reached a dilemma by the 1970s, where if protection were eliminated, the budworm would affect greater areas than was the case before any management took place. In this state, the forest is chemically dependent—an addict of sorts—if continual growth of the industry is desired. It seems that it may be inevitable for non-target species to suffer as long as the industry chooses to increase production by substitution of human control for natural control.

The past concerns that are still most outstanding are those that can only be resolved by placing limitations on harvesting and forest management activities in general. Respecting the long time period required for forest restoration, i.e. biological control and silviculture, as well as a direct consideration of the importance of biodiversity are difficult because they conflict with the goal of maintaining or increasing the level of harvesting. The SBDSS was designed to improve the efficiency of industry in sustainable timber volume management over the long-term, and some concerns of the past have been indirectly attended to as a result. It must be kept in mind that the system has been designed as an industrial aid, and for this function it seems to offer a lot of hope. Through the limitations and assumptions, what is considered important is defined. Through the design of the SBDSS, wastefulness in forest management (including spray operations) was identified and measures to increase overall efficiency have been put in place. Some of the concerns of the past, brought up by ecologists and citizens for the most part, likely correlated in some way with the concerns of industry, therefore they have been dealt with to a degree. At least one concern of industry, public image, has corresponded directly to a concern of the public and some ecologists: the toxicity of sprays. In the end though, the spruce budworm is still considered an enemy of the industry. Changing this perspective on the budworm would likely involve some redefinition of the human relationship to the forest.

Notes

[i] The species in Lillooet is the western spruce budworm rather than the eastern variety found in New Brunswick. The minor difference can be ignored in this case because Tothill is only illustrating the importance of biodiversity in natural control of *an* insect.

[ii] "Satisfactory" is a relative term. What was meant by this description was that the biological control methods were not as efficacious as the insecticides that were in use at the time.

[iii] Since approximately the mid-1980s, budworm populations have steadily declined and were not at high enough levels to be considered of outbreak status.

[iv] The term "technological reality" is used here instead of just "reality" because all the predictions of these systems were (and are) bounded by the assumptions built into them through data inputs and theoretical understanding of the relevant ecological relationships. The future reality (prediction) is therefore created by the system.

[v] Recently, the statement was made that: "Knowing what causes budworm populations to fluctuate will allow us to build realistic process models (…)" (Sanders 1995, p.92). This is a statement confirming a lack of understanding.

[vi] *Btk* is *Bacillus thuringiensis* variety *kurstaki*, which is the one used to make spray formulations for use on the budworm; this is the one referred to in this paper as simply Bt.

[vii] Pheromone analogs have been used as behavioral disruptors. They are used to confuse the males and interfere with mating. Other control agents that are analogs of chemicals important in normal physiological processes of the budworm also fit under the category of semiochemicals.

[viii] The neem tree produces a substance known as azadirachtin, which is very potent to many insects (Charest 1996).

[ix] Past supporters of silvicultural/biological budworm control described that forests with greater biodiversity would be more resistant to budworm defoliation, but undergoing such an approach involved giving less of an active role to humans and a greater one to natural control agents. Please see previous chapter.

[x] Clearcutting and fires control have fluctuated since the 1980s, but spraying has gradually declined.

[xi] Planting operations peaked from 1980 to 1986 averaging about 26 million trees per year, and have fluctuated greatly since then.

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